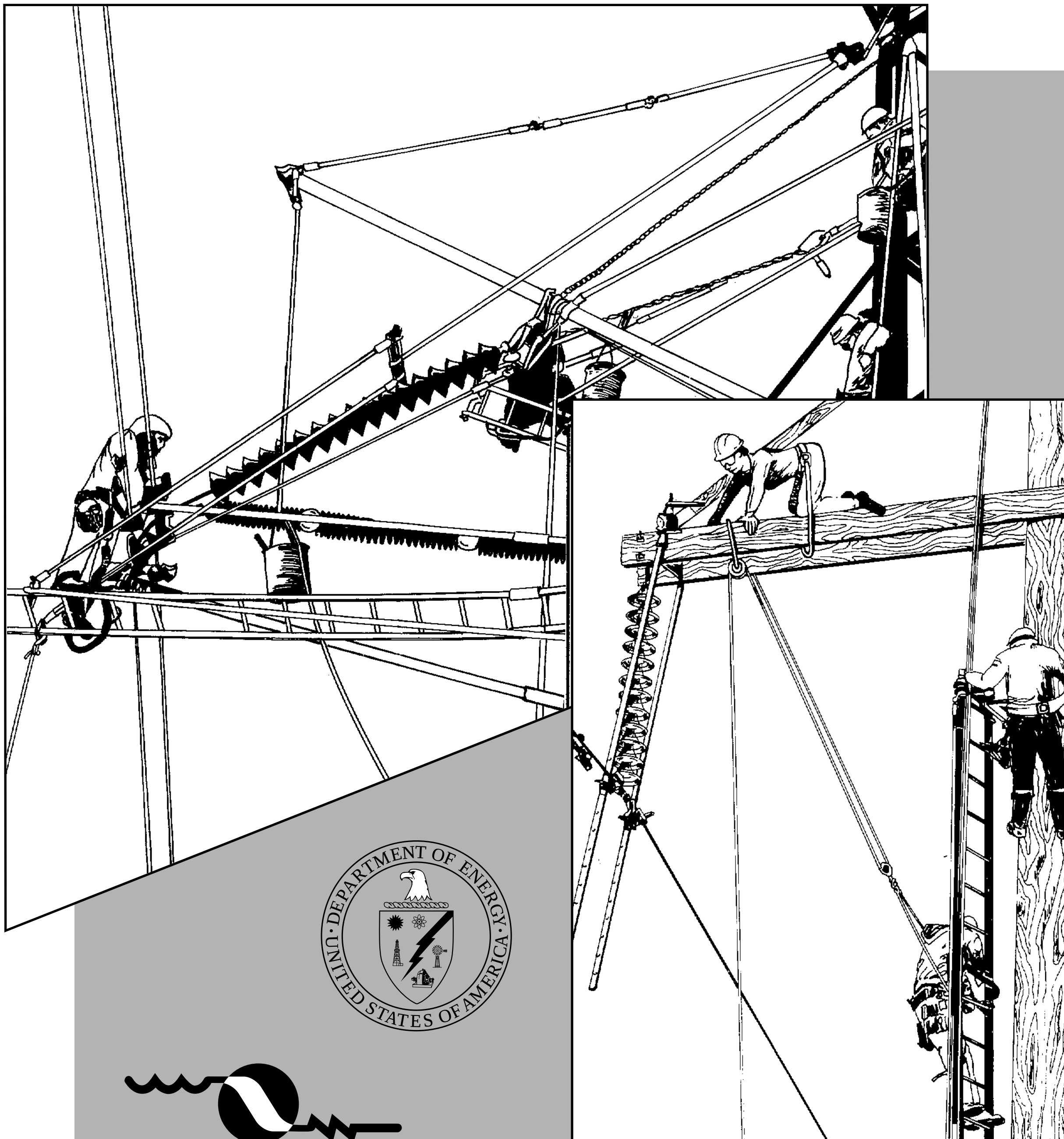
LIVE-LINE MAINTENANCE

Chapter 3

August 1995



WESTERN AREA POWER ADMINISTRATION

LIVE-LINE MAINTENANCE

AUGUST 1995

WESTERN AREA POWER ADMINISTRATION
POWER SYSTEM MAINTENANCE MANUAL
CHAPTER 3

Approved for Publication and Distribution

Steven F. Schweitzer
Director, Division of Maintenance

8/12/95
Date

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Preface

This guide is issued by the Western Area Power Administration (Western) and is designed to provide specific guidelines, instructions, procedures, and criteria for performing live-line work on Western's electrical facilities. Procedures and guidelines are in accordance with Western's Power System Safety Manual (PSSM), Equipment and Motor Vehicles (section 5), Substation and Communication Facility Work (section 11), Live-line Hotstick Work (section 13), and Live-line Barehand Work (section 14). Corrections or comments concerning this guide may be addressed to:

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1. General

Historical background information for live-line maintenance can be found in appendix A.

1.1 Purpose. The purpose of this chapter is to establish clear and consistent guidelines for live-line work. The term live-line maintenance, as used in this manual, includes maintenance activities using the hotstick or the barehand technique. Live-line maintenance is a procedural activity and does not include such activities as switching, climbing inspection, conductor stringing, etc.

1.2 Scope. These guidelines and live-line work procedures supplement the requirements of Western's PSSM, and therefore shall be complied with by Western's operation and maintenance (O&M) employees performing work on energized transmission lines and energized equipment in Western facilities. In the event of a conflict between the requirements contained in this chapter and those contained in the PSSM, the PSSM shall prevail until the conflict can be resolved.

1.3 Definitions and Interpretations

1.3.1 Interpretations. The stated interpretations for the following words shall be applied throughout this chapter:

(1) "May" - Permissive choice.

(2) "Shall" or "Must" - Mandatory under normal conditions.

(3) "Will" - Mandatory, but allowing the responsible employee or party some discretion as to when, where, and how.

(4) "Should" - Advisory. These statements represent the best advice available at the time of printing.

(5) Male pronouns and related terms are used to reference both male and female employees.

1.3.2 Definitions. In addition to these definitions, the following shall also prevail throughout this chapter: PSSM appendix G, "Glossary," and Power System Operations Manual (PSOM) Chapter 1 section II, "Definitions."

Acceptance Test - The required testing provided by the manufacturer of the product in accordance with specific sections of National Standards, such as American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), etc. Acceptance tests shall be specified as a requirement in Western's procurement specifications. Purchasing products in accordance with ASTM, ANSI, etc., insures the performance of all applicable tests.

Barehand Technique - Live-line work performed by placing the worker at the same potential as the conductor/equipment while maintaining the required clearances from the energized conductor/equipment to ground.

Bond - The electrical interconnection of conductive parts designed to maintain a common electrical potential.

Cable Cart - A metal or metal-lined, open-topped platform equipped with weight-bearing conductive wheels, capable of being attached to powerline conductors, and used to transport workers along the conductors.

Certified (employee, craftsman, or professional) - One who possesses a certificate, or has been certified by a recognized authority, attesting that he has been trained or tested and has demonstrated proficiency in performing live-line work.

Conductive Clothing - Metallic or metal-impregnated-cloth protective clothing worn by electrical workers for protection from electrostatic effects of high-voltage energized conductors and equipment.

Damage - Loss in value, usefulness, etc., to property or things. Harm causing any loss.

Defective - An item no longer suitable for the purpose for which it was intended.

Energized - Electrically connected to a source of potential difference, or electrically charged so as to have a potential different from that of ground.

Grounded - Connected to earth or to some conducting body that serves in place of the earth.

Hazard - Anything which can potentially endanger personnel, impair safe working conditions, and conceivably cause injury or loss of life.

Hot Line Order (capitalized) - Is a statement with documentation from an Operations Supervisor to a Job Supervisor that the automatic reclosing is turned off and that the equipment covered by the Hot Line Order will not be intentionally reenergized until contact has been made with the job supervisor holding the Hot Line Order. This allows specific work to be done on or near a line or other equipment without requiring that it be disconnected from all sources of electrical energy. The equipment is to be considered energized or "hot."

Hotstick Technique - Live-line work performed by a worker placed at ground potential while maintaining the required electrical clearances from ground to the energized conductor/equipment.

Insulated Aerial Device - Vehicular-mounted articulating or telescoping boom-type personnel lift device equipped with fiberglass boom section(s) for insulation and metal-lined fiberglass bucket(s) or metal platform for personnel support, designed, constructed, tested, and certified in accordance with ANSI A92.2, "Vehicle Mounted Elevating and Rotating Work Platforms."

Insulated Live-Line Tools - All hand-held and structure-mounted tools having an insulated section or non-conductive property that is designed, tested, and approved for contact with energized conductors.

Job Hazard Analysis - A study of a job or activity to 1) identify hazards or potential accidents associated with each step or task and 2) develop solutions that will eliminate, modify, or prevent such hazards or accidents.

Job Supervisor - Any person authorized to request, receive, and release Clearances and Hot Line Orders and who is charged with the responsibility for the job.

Live-Line Maintenance - Maintenance activities performed on energized conductors or equipment with a phase-to-phase voltage exceeding 600 volts by the hotstick technique or 69 kV by the barehand technique. Live-line maintenance does not include such activities as switching, hardware tightening, climbing inspection, hole digging, pole setting, conductor stringing, etc.

Live-Line Tools - Equipment used in live-line maintenance procedures including but not limited to hot-sticks, pole gins, switching sticks, and insulated ladders.

Minimum Electrical Approach Distance - The minimum working distance from energized conductors and equipment for personnel. This includes: 1) The minimum approach distance to be maintained by workers and objects carried by them (except insulated live-line tools) from energized conductors and equipment; 2) The minimum distance workers shall maintain themselves and their support platforms, or be maintained by other means, from grounded parts or other energized conductors or equipment when approaching, leaving, or bonded to an energized conductor or piece of equipment; and 3) The minimum distance any piece of mechanized equipment may be set up or operated from an energized conductor or piece of equipment by other than properly trained and supervised O&M personnel.

Nonconductive Rope - A flexible rope of twisted or braided synthetic polymer fibers maintained in a clean dry condition for use in conjunction with live-line maintenance. Nonconductive ropes can be used as hand-lines or taglines.

Nondestructive Evaluation (NDE) - Determination of the condition of a product without over-stressing or deteriorating any feature or component part of the product. Some of the accepted NDE methods are X-ray, ultrasonics, magnetic particle, dye penetrant, dielectric, load-deflection, and acoustic emission.

Procedure - A particular course of action or way of doing live-line work.

Safety - The art of performing any activity in an accident-free manner.

Structure - Material assembled to support conductors or associated apparatus used for transmission and distribution of electricity.

Worker - Any person authorized to inspect, service, repair, or otherwise be in contact with equipment. The term normally applies to a craftsperson rather than an “engineer,” “inspector,” or “supervisor.”

1.4 Variances. Variances from the requirements of this chapter may be granted in accordance with paragraph 1.4 of the PSSM.

2. Administrative Requirements

2.1 General. Each employee involved in live-line maintenance activities is responsible for being knowledgeable in the applicable safety requirements and proper live-line procedures. Managers and supervisors are responsible for ensuring that each worker complies with these guidelines and procedures.

2.1.1 Hot Line Order. Live-line maintenance shall be performed under an authorized Hot Line Order (HLO) and all associated automatic reclosing devices shall be deactivated and properly tagged. Work or tests shall not be performed on protective relays, control circuits, or communications systems which could result in a loss of control or disabling of circuit breakers involved in the HLO or a loss of communications between crews and the operations center.

2.1.2 Electric Storms. Live-line work shall be discontinued while there is any indication of lightning or other inclement weather in the surrounding area.

2.2 Written Procedures. A written procedure shall be available for each type of live-line maintenance performed. Each written procedure shall specify the minimum crew size required by classification, the principal tools to be utilized, and each major step in the procedure to be performed. Apprentices must meet the requirements for section 2.4. Procedures shall be periodically reviewed or updated to reflect current work practices, safety concerns, and new equipment. The specific written procedure for the live-line maintenance to be performed shall be available to the crew at the tailgate safety meeting. This procedure will be discussed during the tailgate safety meeting held before performing the live-line maintenance. Live-line maintenance must not be attempted with less than the minimum number of qualified personnel as stated in each written procedure.

A written Job Hazard Analysis (JHA) is required for live-line maintenance. A JHA is an integral part of the preparation for live-line work, and as such, it shall be reviewed and discussed prior to engaging in the live-line work.

Changes to the written procedure made during the work shall be developed through discussion among experienced craftsmen and supervisory personnel.

2.3 Supervision. Live-line maintenance shall be monitored by a supervisor or acting supervisor trained and certified. The supervisor shall observe and direct the work while maintenance is being performed and is to remain on the jobsite in nonwork status and pay strict attention to the ongoing procedural activities while procedural live-line work is being done. The supervisor shall be aware of the physical and mental condition of each crew member. No one, including the supervisor, shall be allowed to work in a condition that could jeopardize the safe operation of the crew or equipment.

2.4 Craftsmen Instruction and Certification. Only certified personnel shall perform or supervise work on energized lines or equipment. Certification for live-line work should ensure that an individual is not only knowledgable but also competent in performing work on energized equipment. Exception: During training sessions, personnel may be uncertified. The step of an apprentice and the extent of his specific involvement in live-line training is left to the Area/District. The Division Director designated by the responsible Area or District Manager shall certify that personnel performing live-line maintenance have satisfactorily completed:

(1) Certification. Certification is required for those performing the barehand or hotstick technique. If certification is received in the barehand/hotstick technique, then a separate hotstick technique certification is not required. However, if hotstick technique certification is received and a worker needs to perform barehand work, the barehand/hotstick certification must be completed. Hourly requirements do not include travel time.

(a) Barehand/Hotstick Technique. A 64-hour training program consisting of a combination of classroom and hands-on or on-the-job training is required, which includes competency testing. The classroom portion will include discussions on the applicable safety rules and maintenance procedures.

(b) Hotstick Technique. A 32-hour hotstick training program consisting of a combination of classroom and hands-on or on-the-job training is required, which includes competency testing. The classroom portion will include discussions on the applicable safety rules and maintenance procedures.

(2) Physical Condition. Craftsmen shall pass an annual physical examination in accordance with the current edition of WAPA Order 3339.

Recertification is not a requirement. However, additional training may be done at any time.

2.5 Supervisor Instruction and Certification. The Division Director designated by the responsible Area or District Manager shall certify that supervisors of live-line maintenance have satisfactorily completed:

(1) Certification. Supervisors shall have previous journeymen certification in the techniques they are supervising and be current in the applicable safety rules and maintenance procedures. Authority to supervise barehand/hotstick techniques should be documented by the individual's supervisor.

(2) Physical Condition. Supervisors shall pass an annual physical examination in accordance with the current edition of WAPA Order 3339.

2.6 Records. Initial certification for each individual shall be recorded and kept in the employees personnel file. A copy shall be kept at the duty station.

3. Live-Line Tool and Equipment Use and Care

Only tools and equipment designed, tested, and manufactured approved for live-line maintenance shall be used. Wood hotsticks are prohibited. The equipment shall be inspected and tested in accordance with the Institute of Electrical and Electronic Engineers (IEEE) Standard 978, the manufacturer's recommendations, and the Area or District Office's instructions. Proper care of live-line tools, including substation switch sticks, fuse sticks, and grounding sticks, will ensure that they are safe to use. Each Area and District shall maintain the live-line equipment and document test results. A video, "Inservice Testing and Care of Live-Line Tools," is available from the Division of Power System Maintenance (A2300) at Headquarters.

3.1 Hotsticks

3.1.1 Inspection. Hotsticks shall be visually inspected for signs of damage before each use. The trunnion, jack screw, and tension puller assemblies should also be inspected. The purpose of the inspection is to look for visible damage to the steel jack screw thread and/or visible significant wear in the bronze trunnion threads. The inspection should include the following:

(1) Disassemble (unscrew) the trunnion assembly from the jack screw.

(2) Clean both elements in a suitable solvent using brushes if necessary to thoroughly clean the thread roots.

(3) Inspect the bronze trunnion assembly for visible wear on the internal acme thread and smooth free-running of the ball thrust bearing.

(4) Inspect the steel jack screw for crookedness, rust, wear, nicks, or burrs. Perform a thread wear gauge test if it is available from the manufacturer.

(5) Reassemble and lubricate the components using a suitable lubricant.

Alterations or modifications shall not be made to hotsticks which may adversely affect the electrical or mechanical capability of the tool. Any of the following observations warrant immediate removal of the tool from service:

(1) A tingling or "fuzzy" sensation when the tool is in contact with an energized conductor or piece of equipment.

(2) A deterioration on the surface of the fiberglass reinforced plastic (FRP) rod (i.e., a lack of glossy appearance, cuts, gouges, dents, or delamination).

(3) An electrically stressed tool showing evidence of tracking.

(4) Tools showing evidence of bent or cracked components.

(5) Evidence of overloading. For example, deformed rivets indicate that excessive mechanical loading has occurred and has weakened or sheared the bond between the ferrules and the FRP rod.

3.1.2 Cleaning and Care. Live-line tools must be maintained in a clean condition. Workers should use clean hands or gloves while handling tools to avoid contamination of the dielectric surface. The surface of each tool must be inspected for contamination such as dirt, creosote, or grease. Contaminants should be removed with a clean, absorbent cloth or paper towel. Wipe the clean tool with a silicone-treated cloth. If wiping does not remove the contaminant, follow the manufacturer's recommendations for cleaning and resurfacing.

While performing live-line work, live-line tools shall be placed on tarps or special tool holders. They shall not be placed on the ground or against sharp objects such as barbed wire fences or steel towers.

3.1.3 Storage. Live-line tools, when not in use, shall be kept in weatherproof enclosures and stored in a dry and warm location when possible. Sticks may be stored in clean, dry polyvinyl chloride (PVC) tubes secured in a protected location where indoor storage is not available. Electric heaters in hot-stick trailers are designed to prevent condensation and are not recommended for drying live-line tools. The hotstick trailer should be periodically inspected for signs of deterioration.

3.1.4 Testing. Fiberglass-reinforced plastic (FRP) insulated live-line tools shall be electrically tested once every 2 years and the results documented. Testing shall be in accordance with procedures set forth in appendix B.

3.2 Insulated Ladders. Workers will ensure continuous attachment during the critical transition between the structure and ladder. Rigging, including safety chains and/or straps, shall be secured before allowing workers to access the ladder. Ladders having rungs with deteriorated anti-slip surfaces shall be removed from service and be repaired or replaced.

3.2.1 Vertical. Insulated ladders used in the vertical position shall be connected in a manner that will not allow possible separation from the structure. Insulated ladders shall be equipped with nonconductive safety ropes along both outside rails from the top rung to the third rung from the bottom or to the ladder manufacturer’s eyelets. All work at elevated heights must adhere to fall protection requirements outlined in section 16 of the PSSM and chapter 2 of the PSMM.

3.2.2 Horizontal. Insulated ladders used in the horizontal or near-horizontal position shall be secured to the structure by clamps with a safety sling placed around a structure member and a ladder rung. An insulated suspension assembly shall be attached to the outer end of the ladder. The upper end of the insulated suspension assembly should include a synthetic strap ratchet hoist or live-line blocks for vertical control of the end of the outboard ladder. A minimum of two hotline tag ropes will be attached to the side rails of the ladder at the support pole’s attachment points for horizontal control.

3.2.3 Traveling. Prior to using the traveling-block supported ladder, inspect the static attachment points on the adjacent structures and install safety grips; and for traveling ladders, the traveling block system shall be latched or pinned on the overhead ground wire or phase conductor. Securely pin the traveling block to the rails of one end of the ladder in a manner to provide maximum stability and support. The safety ropes shall be connected to attachment points of the insulated ladder and the traveling block system. One nonconductive rope tagline shall be attached to the side rails near the lowest rung. The traveling-block insulated ladder shall be controlled using nonconductive rope taglines used in conjunction with rope snubbing devices. The traveling block supported insulated ladders shall be controlled using capstan hoists attached to anchorages. The capstan hoists shall have individual “start-stop” facilities where the operator can reach them. Control side movement of the insulated ladder using nonconductive rope handlines or taglines.

The nonconductive rope in block-to-block handlines shall have a minimum breaking strength of 24,000 newtons [5,400 pounds]. The double-block assemblies shall each have a load capacity greater than 680 kilograms [1,500 pounds]. Capstan hoists shall have a load rating of at least 340 kilograms [750 pounds]. The anchorage for the capstan hoists shall be capable of supporting at least 680 kilograms [1,500 pounds].

3.3 Nonconductive Handlines and Taglines. Nonconductive synthetic rope handlines and taglines are considered live-line tools and must be treated accordingly. Natural-fiber rope shall not be used on or near energized features. Dry, nonconductive handlines and taglines may be used in hotstick or barehand procedures provided the minimum approach distances (energized phase-to-ground or energized phase-to-phase) in appendix D are not violated.

Nonconductive rope should be stored in a clean, dry location to prevent mechanical damage or contamination. Handlines and taglines shall be stored in and used from dedicated nonmetallic canisters. Workers handling the handlines and taglines shall wear clean gloves to minimize contamination. Dirty or damaged nonconductive handlines and taglines shall be removed from live-line service. Wet handlines and taglines shall be dried and carefully inspected before being stored or reused for live-line maintenance. Rope handlines and taglines shall be tested phase-to-ground at the jobsite each day prior to use. A simple means of testing is to tie the rope to the structure and push the rope into the energized conductor with a hotstick. Emphasis should be placed on the visual inspection.

3.4 Personal Protective Equipment.

3.4.1 Conductive Footwear. Protective footwear is not required when using hotstick procedures; however, conductive footwear may be worn at anytime during live-line work. Personnel using the barehand technique shall wear conductive footwear 1) when working from a metal-lined or open-metal platform aerial device, 2) when transitioning between an insulated ladder and a steel structure, and 3) when transitioning a tower boom-supported platform or conductor cart from a steel structure at voltages above 200-kV nominal phase-to-phase. Conductive socks or leg straps should be used. Metal surfaces on manlifts and conductive footwear shall be kept clean to ensure good electrical contact.

3.4.2 Conductive Clothing. Protective clothing is not required when using hotstick procedures; however, conductive clothing may be worn at anytime during live-line work. Personnel using the barehand technique shall 1) wear a parka or jacket and boots and gloves when working from a metal-lined platform aerial device and 2) wear a parka, pants, boots, and gloves when working from an insulated ladder or open-metal platform.

3.5 Live-Line Power Tools. Power tools using hydraulics, pneumatics, etc., as a prime mover should be kept in the bucket or on the platform at equal potential to the operator. If it is necessary to have tool components at ground potential, it is essential to ensure that the dielectric requirements between ground potential and the working potential are adequate and that voids in hydraulics do not occur.

3.6 Miscellaneous Tools. Tools that are not carried in a tool belt should be raised to the worker(s) in tool bags. Hand tools should be kept in tool bags or secured when not in use. The work area should be free of clutter.

To verify the minimum approach distance, insulated hand-held live-line tools shall be fitted with safety hand guards or visible marking located in accordance with appendix D. It should be noted, however, that safety hand guards are dynamic and can give a false sense of security. The worker maintaining a constant physical awareness of the clearances is more important. A calibrated insulated measuring stick or equivalent may also be used to verify the minimum approach distance.

4. Vehicles

4.1 General. Vehicles and hotstick trailers should not be parked beneath the conductors while the job is in progress unless absolutely necessary. To ensure that the vehicle will not be moved when being used as a snubbing device, it is recommended that the keys be removed from the ignition.

4.2 Grounding. Vehicle grounds create a fault current return path if the insulation of an insulated boom fails or if a noninsulated vehicle comes in contact with an energized line. In the event of either, dangerous step and touch potentials are present near grounded vehicles. Workers must keep nonwork related equipment and themselves at least 10 feet away from grounded equipment and structures when practical. Vehicles with an insulated or noninsulated boom shall be grounded in accordance with the PSSM section 10 and the PSMM chapter 1, Personal Protective Grounding.

5. Hotstick Technique

5.1 Operating Practices. Workers and support equipment (ladders, aerial device, wood structure members, etc.) used in the hotstick technique shall be considered to be at ground potential. Insulated ladders and booms do not require preoperative dielectric tests. Prior to performing the hotstick technique, the supervisor or other designated person shall 1) obtain and read the HLO and 2) determine there is adequate phase-to-phase and phase-to-ground climbing and working space for the voltage being worked. The insulated tools shall be cleaned and marked for the voltage being worked. Actual measurements should be used to determine the location of grounded and energized parts in the vicinity of the proposed work.

5.2 Minimum Approach Distances. Personnel at ground potential shall keep themselves and objects they carry (except insulated live-line tools) outside the minimum approach distances specified in appendix D.

5.3 Insulator Replacement.

5.3.1 Nonpolymer Insulators. The decision to replace insulators is usually based on visible damage such as cracks, breaks, or electrical flashover. Broken skirts and "cobs" will often have an insulation value but should be considered electrically defective until tested. On the other hand, insulators that do not show mechanical damage may fail electrically. This occurs predominately in tension insulator strings. Therefore, tension insulator strings (dead-ends and angles) shall be tested to ensure that electrically defective insulators are identified prior to replacement using the hotstick technique. It is also recommended that suspension insulator strings be tested. Post-type and multinet porcelain horizontal struts can usually be tested with a single prong tester. Replacement nonpolymer insulators should be electrically tested prior to installation.

If the insulator string has at least the minimum required number of electrically good insulators (see table 6.1, page 21), the string may be worked using the hotstick technique. Otherwise, the insulator string may only be replaced under deenergized conditions. The minimum required number of good insulators varies with structure type, insulator type, elevation, maximum anticipated transient overvoltage, and specific line design. Numbers other than table values may be used where electrical testing has been done for a specific line, and work procedures have been written for that insulation level (i.e., COTP 500-kV line). Any number of bells in an insulator string may be temporarily shunted to perform live-line maintenance provided the minimum electrical approach distance is not less than the requirements specified in appendix D. Shunted insulators shall be counted as defective in the use of table 6.1. The minimum required number of good insulators shall be increased in accordance with climatic conditions (i.e., high altitude, high humidity, etc.). Defective porcelain bells retain 20 to 75 percent of their dielectric strength in dry conditions unless punctured. Broken glass bells have zero dielectric strength.

5.3.2 Polymer Insulators. The testing requirements of 5.3.1 do not apply to polymer insulators for the hotstick technique. Polymer suspension insulators must be visually inspected for carbon tracking and audibly inspected for corona, particularly at the interface of the polymer rod and the insulator skirt. If there is an indication of carbon tracking, severe mechanical damage, or corona, the circuit is to be deenergized before work is done.

5.4 Bonding. Any bonding used in the hotstick technique shall be in accordance with section 6.4, "Bonding and Static Ground Leads."

5.5 Hotstick Maintenance in Substations. Live-line hotstick techniques are permissible in substations where the minimum approach distance can be maintained in accordance with appendix D.

6. Barehand Technique

6.1 Operating Practices. Barehand work involving hotstick techniques shall comply with section 5.

Workers using the barehand technique shall be considered to be at the potential of the energized circuit when in the working position and must maintain the required minimum approach distances specified in appendix D. Prior to performing the barehand technique, the supervisor or other designated person shall 1) obtain and read the HLO and 2) determine there is adequate phase-to-phase and phase-to-ground climbing and working space for the voltage being worked. The insulated tools shall be cleaned, and the insulated ladders shall be tested prior to use. Actual minimum approach distance measurements should be used to determine the location of grounded and energized parts in the vicinity of the proposed work.

Prior to suspending insulated ladders, support platforms, or conductor carts from overhead ground wires or conductors, the conductor shall be inspected for damage such as worn suspension fittings, bullet damage, ice load damage, etc. Prior to using the traveling ladder, inspect the static attachment points on the adjacent structures and install safety grips.

When it is necessary that an engineer or other specialist participate in a specific test or inspection program involving the use of insulated personnel-support equipment, the engineer or specialist must be accompanied by a certified craftsman and must have received sufficient instruction to perform the inspections and/or tests safely.

6.2 Tools and Equipment.

6.2.1 Insulated Aerial Devices. Aerial devices shall have the minimum dielectric strength required for the voltage being worked.

6.2.1.1 Requirements. Insulated aerial devices used in the barehand technique shall comply with the following requirements:

(1) Aerial device equipment shall be manufactured for performing live-line maintenance and shall only be used according to manufacturer's instructions.

(2) In order to prevent arcing across a vacuum space in a hydraulic line, all insulated aerial devices with hydraulic lines to controls at the platform or bucket shall be equipped with check valves in the lines and an atmospheric relief valve in the hydraulic system at the support platform. When the boom is in an energized attitude, the engine shall not be shut down nor the hydraulic pump disengaged.

(3) The hydraulic system of the vehicle may be used to power hydraulic tools at the support platform if it conforms to ANSI A92.2 1990 standards. Hydraulic driven tools used from insulated aerial devices shall be maintained as part of that aerial device's hydraulic system and not used from other hydraulic systems.

(4) Hydraulic lines for use with hydraulic tools shall neither be built into nor attached to the outside of the insulated boom portion of aerial device equipment.

(5) The support platform of insulated aerial devices may be single or double fiberglass buckets or a single metal platform equipped with an approved open-rail system. Fiberglass buckets shall be metal lined with the liners bonded together on double-bucket equipment. Fiberglass buckets shall not be considered an insulator when using the bare hand technique.

(6) The use of a permanently installed current monitor is recommended for monitoring leak age current in the boom during the barehand technique. An ammeter, calibrated in 10-

INSULATED BOOM AERIAL DEVICE DIELECTRIC TEST REPORT

Area/District: ______________________ Line Crew: ______________________

Vehicle Number: ______________________ Vehicle Manufacturer: ______________________

Boom Manufacturer: ______________________

Date/Time	Weather/Temperature	Feature being worked on and Voltage	Voltage/Leakage Current	(µA) Reading	HLO No.	Supv. Init.

Figure 6.1 - Insulated Boom Aerial Device Dielectric Test Report

microampere (or less) scale divisions, shall be kept with the insulated aerial device. The ammeter shall be tested annually with a certification of the test attached to the meter or its case.

(7) Metal-lined buckets and platforms shall be furnished with a minimum of two barehand bonding leads. A spring-loaded breakaway clamp shall be attached to each bonding lead.

(8) Insulated aerial devices shall be annually inspected and tested in accordance with appendix C.

(9) A minimum approach distance table reflecting the minimum approach distances listed in appendix D shall be printed on a plate of durable nonconductive material mounted so as to be visible to the operator of the boom.

6.2.1.2 Preoperative Tests. Before raising the insulated aerial device into the work position, all controls (ground level and bucket or platform level) shall be checked. In addition, for insulated aerial devices with hydraulic lines to controls at the support platform level, the support platform shall be raised to its maximum height and left in the raised position for 5 minutes for the hydraulic leak down test. Initial contact of an energized conductor shall be made with no one on the support platform or bucket so that the leakage current in the boom may be measured. No one standing on the ground shall be in contact with the vehicle while the leakage current test is being made. The leakage current reading shall be taken while standing on the vehicle before starting work each day, each time a higher voltage is to be worked, and when an additional test is needed. A written record of these tests shall be maintained with the equipment. An example form is shown in figure 6.1. If the dielectric arm-current, after 3 minutes, is less than 1 microampere for each kilovolt of nominal phase-to-ground voltage (refer to table below, rounded up to the nearest 10µA), and relatively the same as previous dielectric arm-current readings from tests on the same voltage and under similar conditions, the work platform may be used for barehand work. Work operations shall be suspended immediately upon indication of a malfunction in the equipment.

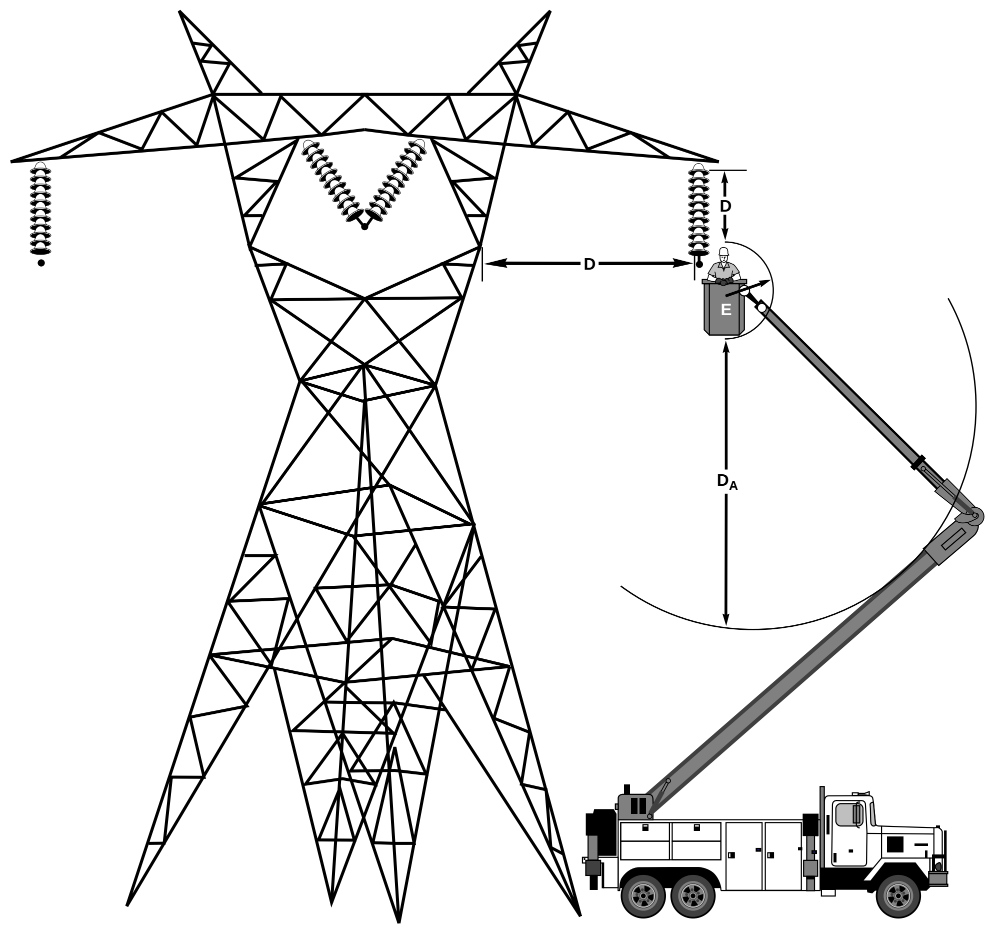
Voltage (kV) Phase-to-Phase	Voltage (kV) Phase-to-Ground	Acceptable Dielectric Current (µA) for Insulated Booms $\mu = 10^{-6}$
72.6 - 121	67	less than 70
138 - 145	80	less than 80
161 - 169	93	less than 100
230 - 242	133	less than 140
345 - 362	200	less than 200
500 - 550	318	less than 320

6.2.1.3 Safety Procedures. When working on the platform, both legs shall be inside the support platform at all times with at least one foot on the bottom of the support platform. Personnel shall be belted to the aerial device. All work at elevated heights must adhere to fall protection requirements outlined in section 16 of the PSSM and chapter 2 of the PSMM.

One person, capable of operating all controls, shall be stationed on the ground near the vehicle when personnel are on the support platform. This person shall keep other persons from walking under the work area and keep them clear of the vehicle when the support platform is elevated. All movements of the lift assembly shall be controlled by the workers when they are on the support platform, except under emergency conditions. Under these emergency conditions, the ground operator shall mount the vehicle by means of an insulated device or such that he does not simultaneously contact the vehicle and ground. No one on the ground shall be in contact with the vehicle or protective ground cable while the support platform is in an energized position.

6.2.1.4 Minimum Approach Distances. A nonconductive measuring device shall be readily accessible to assist employees in maintaining the required minimum approach distance. When approaching energized equipment from an aerial device (see figures 6.2.1.A and 6.2.1.B), the distance (D_A) between the worker envelope (E) and any part of the uninsulated section of the boom must be greater than or equal to the minimum phase-to-ground distance (see appendix D). This is important when working with the boom in a jackknifed position. In addition, the minimum approach distances for the following scenarios must be maintained:

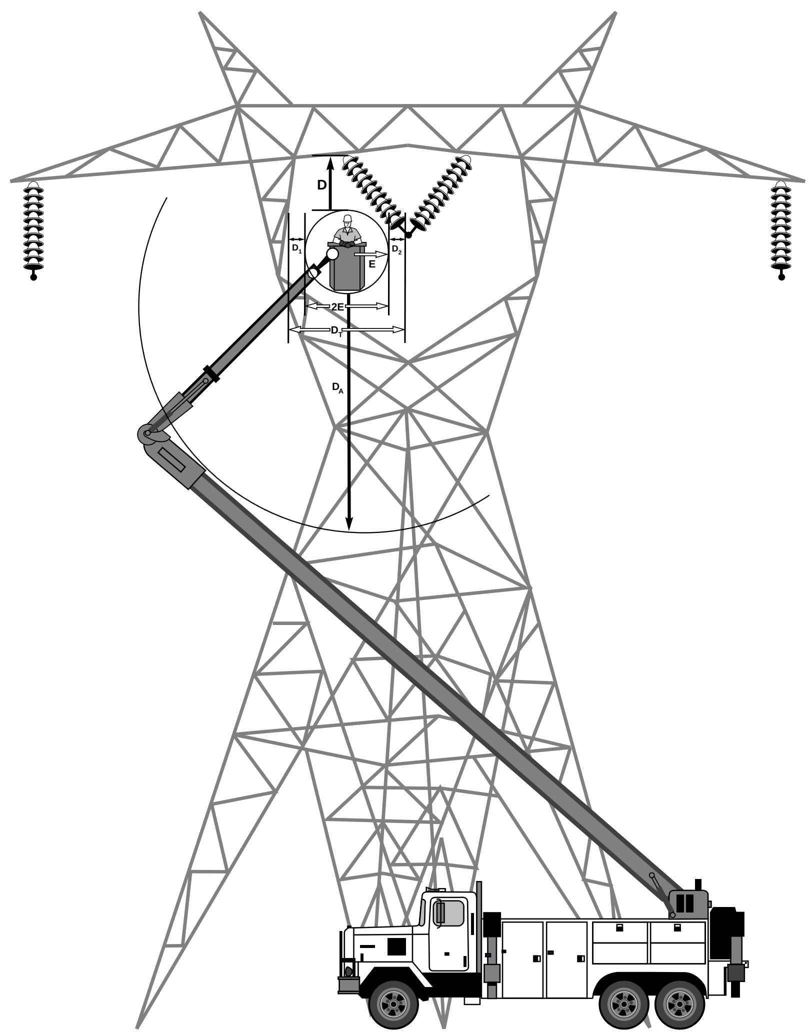
(1) When a worker is accessing the outside phase of a structure, from the outside as shown in figure 6.2.1.A, the distance D, between the worker envelope E, and any part of grounded equipment, must be greater than or equal to the minimum electrical approach distance (see appendix D).



D_A = Distance between the worker envelope and uninsulated truck and boom components. This must be greater than or equal to the minimum electrical approach distance (appendix D).
E = Worker envelope = 4 foot radius.
D = Greater than or equal to the minimum electrical approach distance (appendix D).

Figure 6.2.1.A - Insulated Boom - Worker positioned at Outside of Phase

(2) When a worker is accessing an energized conductor in an aerial device from the inside or between phases as shown in figure 6.2.1.B, the distance D_T must be greater than or equal to the minimum approach distance + 2E, and the distances D_1 and D_2 must be greater than or equal to the minimum electrical approach distance (see appendix D). The worker enve-



D_A = Distance between the worker envelope and uninsulated truck and boom components. This must be greater than or equal to the minimum electrical approach distance (appendix D).
E = Worker envelope = 4 foot radius.
D = Greater than or equal to the minimum electrical approach distance (appendix D).
$D_1 + D_2$ = Greater than or equal to the minimum electrical approach distance (appendix D).
D_T = Total minimum electrical approach distance with worker in the envelope. This must be greater than or equal to 2E plus the minimum electrical approach distance (appendix D).

Figure 6.2.1.B - Insulated Boom - Worker positioned at Inside of Phase

lope is an 8 foot diameter sphere around the worker in the bucket or platform.

(3) For work on the energized terminal end of a bushing, on equipment with a phase-to-phase voltage of less than 200 kilovolts, the support platform must be positioned so that none of the bushing insulation is shunted and the minimum distances to grounded parts and other phases are not violated. For work on the energized terminal of a bushing, on equipment with a phase-to-phase voltage of 200 kilovolts or more, the support platform must be positioned so that no more than 10 percent of the bushing insulation is shunted and the minimum distances to grounded parts and other phases are not violated.

6.2.2 Insulated Ladders. Insulated ladders may be used as personnel support for live-line maintenance using the barehand technique on energized conductors and equipment with a phase-to-phase voltage rating of 115 kilovolts and above, provided minimum distances specified in appendix D are maintained. Only ladder sections made of FRP shall be used as insulated ladders in live-line maintenance using the barehand technique.

6.2.2.1 Preoperative Tests. Insulated ladders shall be tested for leakage current at the beginning of the day, each time a higher voltage is to be worked, and when additional tests are needed. A fused and protected micro. ammeter shall be used for testing the dielectric current through the ladder legs with each leg bonded together at the metering point. If the measured dielectric ladder-current, after one minute, is less than 1/3 microamperes for each kilovolt of nominal phase-to-ground voltage (refer to table below, rounded up to the nearest 10µA), the insulated ladder may be used for barehand work. Written records of these tests shall be kept with the equipment. A sample form is shown in figure 6.2. Live-line maintenance shall be suspended if there is an indication of a malfunction in the equipment.

Voltage (kV) Phase-to-Phase	Voltage (kV) Phase-to-Ground	Acceptable Dielectric Current (µA) for Insulated Ladders $\mu = 10^{-6}$
72.6 - 121	67	less than 30
138 - 145	80	less than 30
161 - 169	93	less than 40
230 - 242	133	less than 50
345 - 362	200	less than 70
500 - 550	318	less than 110

6.2.2.2 Minimum Approach Distances. If the structure does not have the minimum total approach distance required by the following, the line must be worked by the hot-stick method or worked deenergized. The insulated ladder shall be secured and positioned to provide (at least) the minimum phase-to-ground distance specified in appendix D plus a worker envelope that allows for the worker. This distance varies and is dependent on the access procedure performed. This distance has been defined for the following cases:

(1) A worker and insulated ladder is to be swung or hoisted into the inside position of an energized conductor or piece of equipment as shown in Figure 6.2.2.A. When employing this procedure, the worker must move out on the ladder to the minimum electrical approach distance **plus 1.2 meters (4 feet),** prior to the ladder being hoisted into the work position. The worker must remain at this location on the ladder until after the ladder is hoisted or swung the minimum electrical approach distance away from the energized conductor or piece of equipment.

(2) A worker and insulated ladder is to be swung or hoisted into the outside position of an energized conductor or piece of equipment as shown in Figure 6.2.2.B. When employing this procedure, the worker must maintain the minimum phase to ground distance specified in Appendix D prior to the ladder being hoisted or swung into the work position. The worker must remain at this location on the ladder until after the ladder is hoisted or swung the minimum electrical approach distance away from the energized conductor or piece of equipment.

INSULATED LADDER PREOPERATIVE TEST REPORT
LIVE-LINE BAREHAND TECHNIQUE

Area/District: ____________________ Line Crew: ____________________

Insulated Ladder No.: ____________________

Date/Time	Weather/Temperature	Feature being worked on and Voltage	Voltage/Leakage Current	(µA) Reading	HLO No.	Supv. Init.

Figure 6.2 - Insulated Ladder Preoperative Test Report

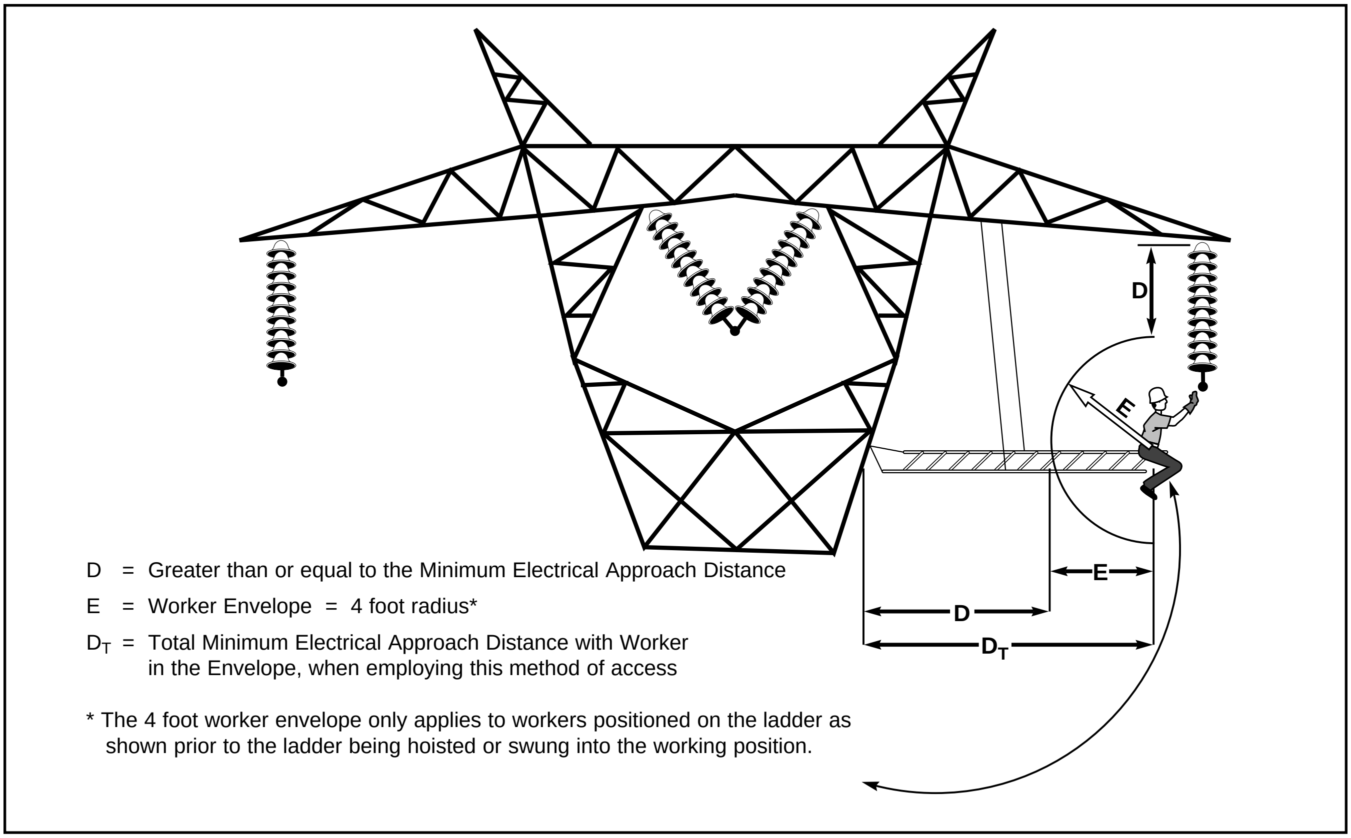


Figure 6.2.2.A - Insulated Ladder - Worker Swung into Inside of Phase

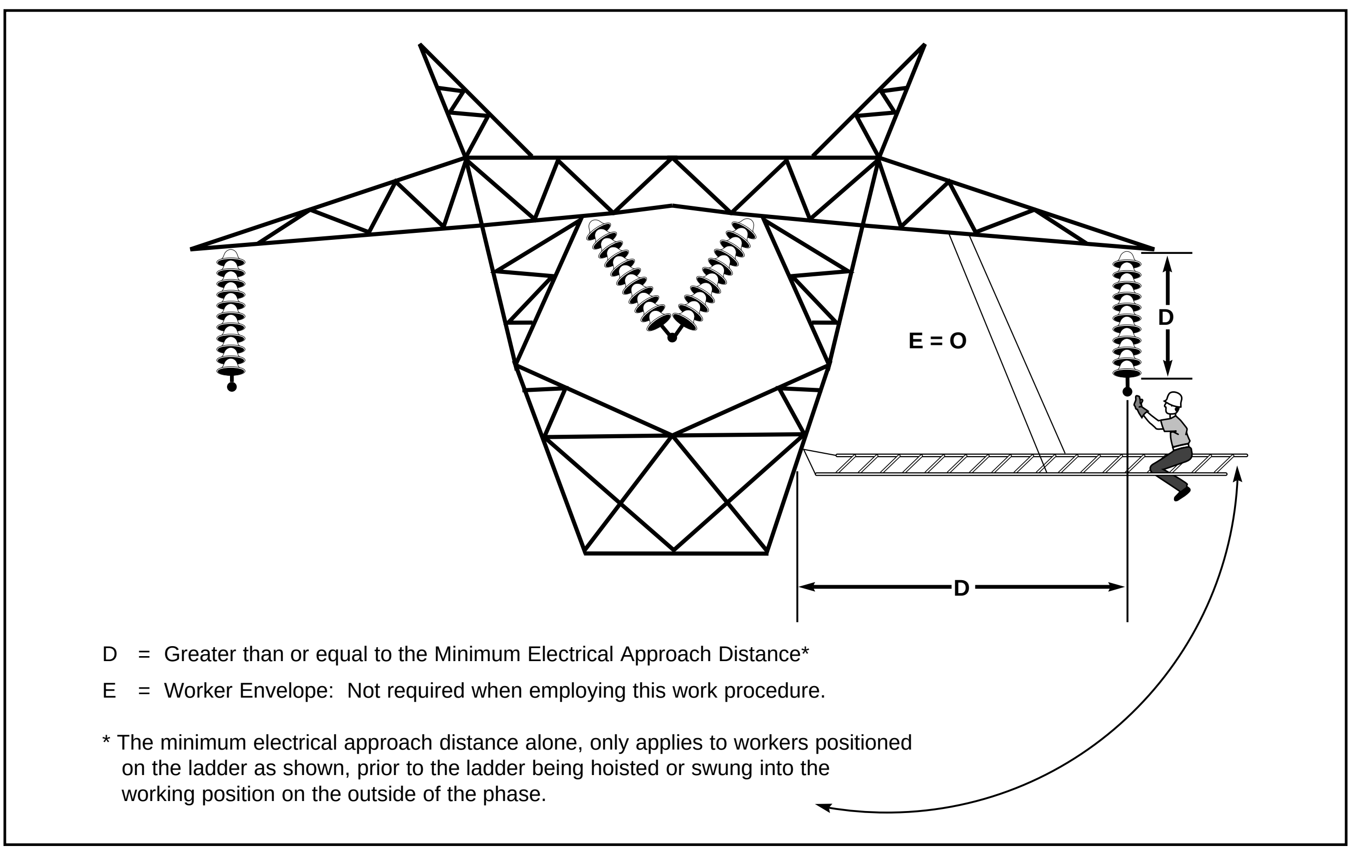


Figure 6.2.2.B - Insulated Ladder - Worker Swung into Outside of Phase

(3) For ladders mounted in a fixed position between an energized phase and ground, the clear length of the ladder between the support bracket and the point of contact with the phase must be the minimum approach distance **plus 2.4 meters (8 feet)** before the worker can transition on the ladder as shown in Figure 6.2.2.C. The ladder must not be attached to the point of contact (energized end) but fully supported from the structure (de-energized end) only.

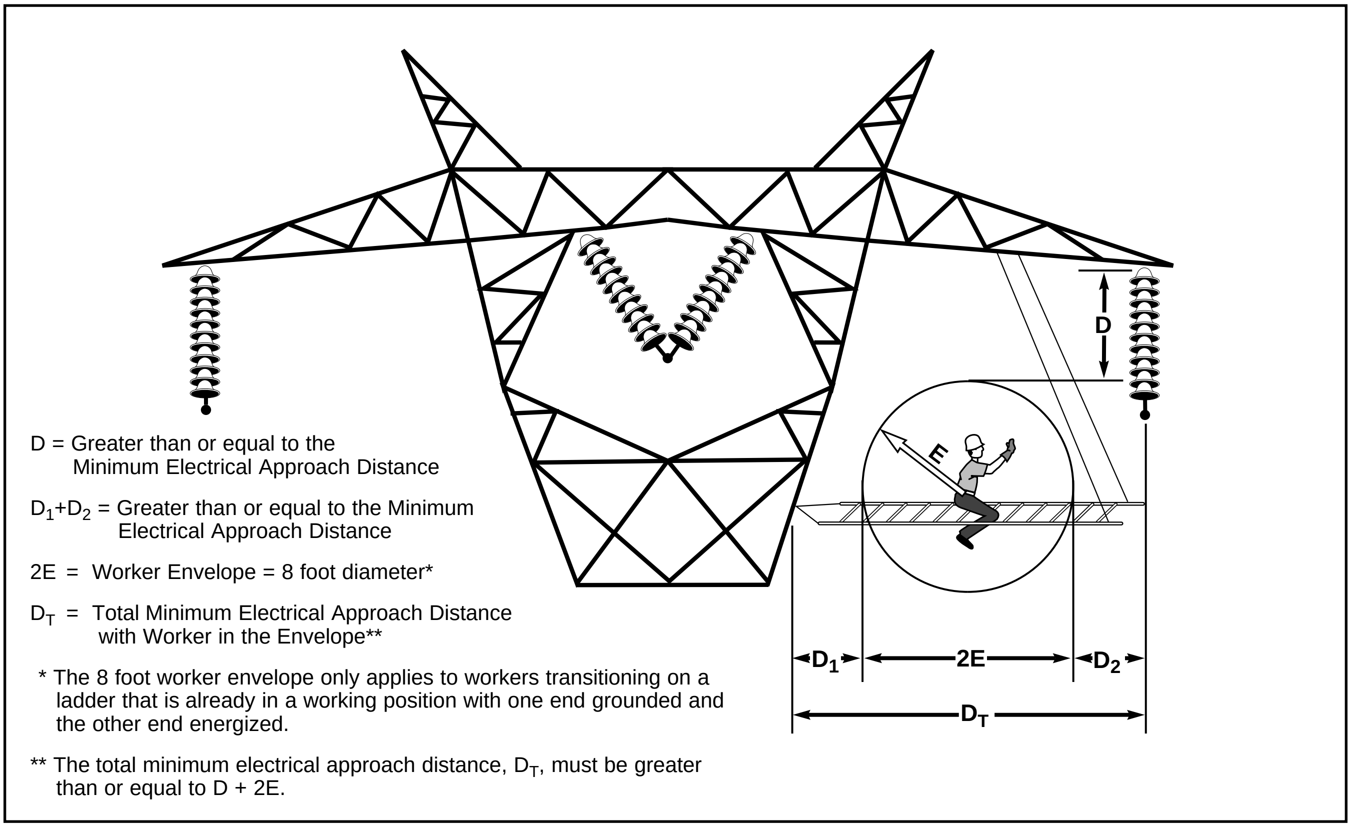


Figure 6.2.2.C - Fixed Insulated Ladder - Worker Transitions to Energized End

6.2.2.3 Usage. A craftsperson on the insulated ladder may use a live-line tool attached to the energized conductor or piece of equipment to help guide himself to and from the bonding position. The live-line tool shall be removed when the worker is bonded to the energized conductor or piece of equipment. Neither the energized end of the insulated ladder nor the worker shall be solidly fastened to a conductor, insulator string, or other component so that in the event of an accident the worker may be pulled free without having to aid in his own rescue.

Before working on an energized conductor or piece of equipment, the worker on the insulated ladder shall bond his conductive clothing to the conductor or piece of equipment by means of a spring-type breakaway clip attached to a conductive clothing bonding lead. Additionally, if two workers are working at the same location on an insulated ladder, they shall bond their conductive clothing together.

Once the worker is bonded to the energized conductor or piece of equipment, tools may be passed to the worker only after the tools are touched to the energized conductor or piece of equipment.

6.2.3 Nonconductive Rope-Supported Platforms. Nonconductive rope-supported platforms may be used as personnel support for the barehand technique. Their use is limited to energized conductors and equipment with a phase-to-phase voltage rating of 115 kilovolts and above. Minimum approach distances listed in appendix D must be maintained.

The nonconductive rope in the two-block handline shall have a minimum breaking strength of 24,000 newtons (5,400 pounds). The double-block assembly shall have a load capacity greater than 680 kilograms (1,500 pounds). If a capstan hoist is used, it shall have a load rating of 340 kilograms (750 pounds) or greater. The anchorage for the capstan hoists shall be capable of supporting 680 kilograms (1,500 pounds).

Various types of support platforms may be used for personnel support. These include a Bosun's chair, a basket or bucket, a tree-trimmer's saddle, or a ladder. The support platform to be used shall be attached to two double-block handlines in a manner that will provide stability. The support platform and component parts shall have a minimum load rating of 227 kilograms (500 pounds).

The support platform shall be controlled using properly-sized capstan hoists which are attached to anchorages. The capstan hoists shall have individual "start-stop" facilities where the operator can reach them. Side movement of the support platform shall be controlled using nonconductive rope handlines or taglines. Mark the minimum distance on the nonconductive rope handlines to maintain the minimum distance from the overhead ground wires and phase conductors.

The worker on the nonconductive rope-supported platform shall adhere to fall protection requirements outlined in section 16 of the PSSM and chapter 2 of the PSMM. Certain types of support platforms, such as a Bosun's chair or tree-trimmer's saddle, may not require additional safety retention. When retention equipment is used, the worker shall adhere to fall protection requirements outlined in section 16 of the PSSM and chapter 2 of the PSMM. The worker on the support platform shall bond his conductive clothing to the energized conductor or piece of equipment by means of a spring-type breakaway clip attached to a conductive clothing bonding lead before working.

6.2.4 Cable Carts. Cable carts may be utilized as support platforms for the barehand technique on energized conductors. Their use is limited to a phase-to-phase voltage rating of 115 kilovolts and above and a phase spacing of at least 3 meters (10 feet).

The cable cart shall be metal or metal lined with at least four weight-bearing, conductive wheels on the support mechanism. The support mechanism shall be hinged for installation on the conductors and may be motor driven. A spring-mounted bonding wheel shall be attached to the framework. The cable cart shall be equipped with safety chains or other suitable means to prevent the cable cart from accidently falling free from the conductors. All components of the cable cart shall have a load rating of at least 500 pounds (227 kilograms) with an overload capacity factor of 3.

The cable cart may be raised to its position on the conductor by means of nonconductive handlines attached to the conductors or overhead ground wires. The worker preparing to position the cart on the conductor shall not make contact with the cart until it is at the same potential as the worker. This can be accomplished either by allowing the cart to be pulled up against the conductors to which the worker is bonded, or by having the worker reach out and energize the cart with a wand or bond. Once the worker is bonded to the energized conductor or piece of equipment, tools may be passed to the worker only after the tools are touched to the energized conductor or piece of equipment.

Workers can access cable carts from most insulated support platforms including insulated aerial devices and insulated ladders. A worker accessing a cable cart from insulated support platforms or accessing insulated personnel-support equipment from a cable cart shall adhere to fall protection requirements outlined in section 16 of the PSSM and chapter 2 of the PSMM.

6.3 Insulator Replacement.

6.3.1 Nonpolymer Insulators. The two types of nonpolymer insulators used on Western's transmission lines are porcelain and glass. Porcelain insulators have a colored surface and when chipped leave a white surface whereas glass insulators are translucent, and have a tendency to shatter rather than chip. The decision to replace nonpolymer insulators is usually based on visible damage, such as cracked or broken skirts or electrical flashover. Broken skirts and "cobs" will often have an insulation value, but should be considered electrically defective until tested. On the other hand, insulators that do not show mechanical damage may fail electrically. Although this predominately occurs in tension insulator strings, all insulators shall be tested for barehand work to ensure that electrically defective insulators are identified prior to replacement. Post-type and multinet porcelain horizontal struts can usually be tested with a single-prong tester. Replacement porcelain or glass insulators should be electrically tested prior to installation.

If the insulator string has at least the minimum required number of electrically good insulators (see table 6.1), the string may be worked using the barehand technique. Otherwise, the insulator string shall not be replaced by the barehand technique. The minimum required number of good insulators varies with structure type, insulator type, elevation, maximum anticipated transient overvoltage, and specific line design. Numbers other than table values may be used where electrical testing has been done for a specific line and work procedures have been written for that insulation level (i.e., COTP 500-kV line). Any number of bells in an insulator string may be temporarily shunted to perform live-line work provided the minimum electrical approach distance is not less than the requirements specified in appendix D. Shunted insulators shall be counted as defective in the use of table 6.1. The minimum required number of good insulators shall be increased in accordance with climactic conditions (i.e., high altitude, high humidity, etc.). Defective porcelain bells retain 20 to 75 percent of their dielectric strength in dry conditions unless punctured. Broken glass bells have zero dielectric strength.

Caution must be used when establishing barehand working procedures at 69 kV and 115 kV. The approach distance required by appendix D may permit work only on outside phases from an aerial device.

Nominal Phase-to-Phase Voltage — kV	Minimum Required Number of Electrically Good Insulators for Live-Line Replacement (see note 1)	
	Porcelain	Glass
34.5 - 72.5	2	Deenergize
72.6 - 121	3	5
138 - 145	4	6
161 - 169	6	8
230 - 242	7	9
345 - 362	8	10
500 - 550	12 (see note 2) 15 (see note 3)	— —

Table 6.1 - Minimum Required Number of Good Insulators

Notes:

(1) The values listed are the per string numbers. A vee string requires the given number in each string.
(2) This number can only be used when a 1.1 m (41 inch) portable protective gap is in place.
(3) This number is based on known transient overvoltages for the COTP.

6.3.2 Polymer Insulators. The testing requirements of 6.3.1 do not apply to polymer insulators for the barehand technique. All polymer insulators must be visually inspected for carbon tracking and audibly inspected for corona, particularly at the interface of the polymer rod and the insulator skirt. If there is indication of carbon tracking, severe mechanical damage, or corona, barehand maintenance will not be permitted. Replacement of nonpolymer insulator strings with new polymer assemblies is an acceptable live-line practice (note: The electrical and mechanical characteristics should be coordinated with A2200, Division of Facilities Design).

6.4 Bonding and Static Ground Leads. Personal safety in barehand maintenance can be critically impaired by improper restraint of bonding straps and static ground leads. It is essential that excessive strap and lead length be restrained.

6.4.1 Conductive Clothing Bonding Leads. Conductive footwear and clothing shall be worn in accordance with paragraph 3.4. Most conductive clothing presently being used has two 6-foot (1.8 meters) bonding leads, one on each side, for working convenience. Storage pockets are provided for the unused bonding lead. The accidental dropping of a bonding lead could cause a flashover when working in confined areas while in an energized condition or when on a grounded feature above energized facilities. The spare bonding lead shall be rolled up and taped before being placed in the storage pocket. The bonding lead being used shall be maintained in the shortest length practicable for the specific working conditions by either rolling and taping or by "knotting" any unneeded length. Bonding straps and connections shall be inspected before use. At least one bonding strap shall remain attached to the energized conductor or piece of equipment while work is being performed. If more than one person is involved in the work, clothing bonds shall be tied at an equal potential location or the personnel shall be bonded together.

When installing a conductor repair sleeve or splice, workers shall be bonded to each side of the work area but this will never substitute for a temporary current-carrying jumper at the work site (see 6.5).

6.4.2 Support Platform Bonding. The bucket or platform used as a support platform on an insulated aerial device is normally bonded to the energized conductor or equipment by means of metallic braid bonding straps. Also, a wand bonded to the support platform is normally used for initial energization and deenergization of the support platform at the higher voltages. The length of the bonding straps and the wand shall not extend below the bottom of the support platform, if dropped.

6.4.3 Live-Line Tool Bonding. If energized conductors or equipment are to be left supported by insulated live-line tools overnight or longer, and rope or nylon straps are an integral part of such suspension, the drop in potential across the nylon or rope may cause deterioration and burning of the nylon or rope. In such cases, the following actions shall be taken to eliminate the potential drop:

(1) If supported by a nonconductive handline from an energized conductor or equipment, the hand line block shall be bonded to the energized conductor or equipment, either by metal clamp support or by wire or metal braid if suspended by a rope "becky."

(2) If supported by an assembly of a combination of FRP poles and nylon ratchet hoist or rope blocks, a wire or metal braid shall be installed across the assembly, from a metallic feature at the outer end of the nylon or rope, back to a grounded feature at the supporting end. If there is no grounded feature at the supporting end, such as a bare wood pole, the bond should be wrapped around the supporting feature.

(3) If supported by a combination of FRP pole and conductive device, such as a chain hoist, attached to a grounded supporting feature by nylon cargo sling, a wire or metal braid shall be installed across the nylon cargo sling.

6.4.4 Static Ground Lead Bonding. When shunting the cold-end insulator in dead-end insulator strings, the shunt cable may be long enough to cause a flashover if dropped. The shunt shall always be kept in a tool bag when not in use. Extra shunt cable shall be rolled up and securely taped during use.

6.5 Conductor Repair and Splicing. When installing a repair sleeve or splicing an energized conductor under a HLO, the jumper and attaching hardware must have a minimum rating of the expected current on the conductor that day. The supervisor working with the dispatcher will establish a current limit to be placed on that line until the splicing is completed.

6.6 Barehand Maintenance in Substations. Live-line barehand techniques are permissible in substations where the minimum approach distance can be maintained in accordance with appendix D. Equipment will be used in accordance with the following basic minimum requirements:

(1) Equipment Grounding. The equipment being used as a fixed-base support for the insulated ladder shall be grounded in accordance with the PSSM section 10 and the PSMM chapter 1, Personal Protective Grounding.

(2) Preoperative Tests. Dielectric ladder-current tests are required for ladders used in the barehand method.

(3) For work at the energized terminal end of a bushing on a circuit with a phase-to-phase voltage of less than 200 kilovolts, the support platform must be positioned so that none of the bushing insulation is shunted by the support platform, with distances from grounded parts and other phases not less than specified in appendix D. For work at the energized terminal of a bushing on a circuit with a phase-to-phase voltage of 200 kilovolts or more, the support platform must be positioned so that no more than 10 percent of the bushing insulation is shunted by the support platform, with distances from grounded parts and other phases not less than specified in appendix D.

7. References

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APPENDIX A - Background Information for Live-Line Maintenance

A.1 Hotstick Technique. While the use of live-line maintenance tools is sometimes considered a recent development in the electrical power industry, forerunners of modern live-line tools made their appearance as far back as 1913. These initial tools were homemade, crude, and bulky; however, they sparked the development of our present efficient and refined tools.

In 1916, a tool that was known as an "electrical hook" was introduced in Atlanta, Georgia. This was essentially a spring-type clamp for tapping energized circuits. The electrical hook necessitated a hotstick for installation purposes, and its use suggested additional tools which were soon developed for grounding and jumper service, applying parallel-groove clamps, handling conductors, pulling cotter pins, and manipulating tie wires. These were followed by a hacksaw, a live-line come-a-long, and saddles which could be attached to the poles for supporting certain tools.

Live-line tools were first accepted for work on lines up to 34 kV, but many linemen were hesitant to perform hotstick operations on this voltage. Because of this fear, many companies restricted live-line maintenance to 22 kV or less. As linemen began to realize that the use of live-line tools always kept them at a safe distance from energized lines, they began to lose their fear of performing this work, and restrictions were gradually relaxed, until by 1930 several companies were permitting live-line operations to be performed on 66-kV lines. This soon rose to 110 kV, and in the late 1930's, the astonishing news was circulated that a west coast line of 220 kV had been successfully worked "hot." Another milepost was passed in March of 1948, when suspension insulators were changed on a 287-kV Hoover Dam-Los Angeles line, using tools especially designed for the job.

In 1959, live-line tools with fiberglass poles were introduced. The fiberglass consists of layers of resin-coated glass fibers wound around and laid lengthwise over a plastic foam core, formed into a single unit by curing in an oven maintained at a constant temperature. It is highly resistant to moisture absorption and damage. The introduction of fiberglass live-line tools materially advanced electric utilities to the present-day live-line maintenance of 345-kV, 500-kV, and 765-kV transmission lines. Western has performed both hotstick and barehand methods of live-line maintenance since its inception in 1977.

A.2 Barehand Technique. The electric utility industry first heard of the live-line barehand technique in late 1960. Conceived by Harold L. Rorden, high-voltage practices engineer for the American Electric Power Service Corporation, the live-line barehand technique was developed and perfected in extensive field and laboratory tests. The tests were conducted in the Ohio Brass Company's high-voltage laboratory, where Rorden was assisted by a co-developer of the new technique, Dr. Charles J. Miller, Jr., Ohio Brass high-voltage research engineer. Holan Division of the Ohio Brass Company designed and produced the aerial-lift equipment used during the development work.

The live-line barehand technique was developed as a result of: (1) rapidly increasing load levels; (2) cumbersome live-line tools; and (3) a lack of parallel or backup facilities. The live-line barehand technique is an alternate method of live-line maintenance. Hotsticks and nonconductive rope are required components of most barehand procedures.

APPENDIX B - Acceptance Testing and Inservice Inspection, Repair, and Testing of Live-Line Tools

B.1 General. Insulated live-line tools purchased and used by Western shall be assembled from fiberglass reinforced plastic (FRP) rod and tube which has been manufactured in accordance with ASTM Standard Specification No. F 711, and various metal or fiberglass end fittings or components which allow the tool to be used for specific types of work on energized electrical conductors and equipment. These live-line tools must withstand high 60-Hz voltages for sustained periods of time, as well as occasional switching surges. Therefore, Western requires acceptance tests on all new insulated live-line tools, as well as biennial inspections and tests for inservice live-line tools.

B.2 Acceptance Testing. Acceptance testing, in accordance with B.4, shall be performed on new insulated live-line tools prior to placing them in service. Acceptance tests performed by the manufacturer may be used to fulfill this requirement.

B.3 Inservice Inspection and Repair of Live-Line Tools. Insulated live-line tools shall be inspected upon each use, and shall be inspected, maintained, electrically tested and repaired at least every 2 years.

(1) Inspection Procedure. When visual inspection indicates that a tool might have been mechanically or electrically overstressed, the tool should be carefully inspected, cleaned, refinished and/or repaired if required, and electrically tested before being returned to service.

(2) Repair Procedure. FRP tools should be cleaned as recommended by the manufacturer. FRP tools should be refinished or repaired in strict accordance with the tool manufacturer's recommendations. Hardware, bolts, and pins should be replaced only with manufacturer's replacement parts. Nondestructive evaluation (Magnaflux, Zyglo, X-ray, or Ultrasonic) should be performed on the mechanical end-fittings after a tool has been subjected to possible overstressing or vibrating loads for an extended period of time. Light spots on FRP poles are caused by impact blows and may or may not have a noticeable effect on the mechanical strength or electrical properties of the tool. However, numerous light spots may indicate abuse, and coupled with surface contamination, may lower the flashover voltage or contribute to insulation degradation. Small surface ruptures or voids beneath the surface can accumulate moisture, or under electrical stress, become ionized leading to progressive degradation of the FRP. Such ruptures and voids should be refinished in accordance with the tool manufacturer's recommendations. All repairs and refinishing should be followed by a high-potential dielectric leakage or AC dielectric-loss test.

B.4 Inservice Electrical Testing. Insulated live-line tools shall be electrically tested every 2 years. Acceptable tests include the high-potential dielectric leakage test (performed wet) and the AC dielectric-loss test.

B.4.1 High-Potential Dielectric Leakage Test. A sample form for live-line tool test records is shown in figure B.1.

(1) Test-Voltage Power Supply. The power supply voltage parameters are dependent upon factors such as electrode design and the distance over which the tests are conducted. The required test voltage capacity for inservice testing is that which will give a voltage gradient of 75 kV per 300 millimeters (1 foot) of the FRP specimen being tested. Either AC or DC may be used. DC testing is less sensitive to slight changes in the geometry of the test setup. Also, DC equipment is much lighter, more compact, and portable enough to perform live-line tool testing in different locations.

(2) Electrode Design. Guarded or shielded electrodes are recommended to avoid the effects of stray and corona currents when measuring the high-potential dielectric leakage current through and

along the surface of the FRP specimen under test. A guarded electrode (corona ring) for the high-voltage terminal is shown in figure B.2, and the grounded shield for the pickup electrode is shown in figure B.3. A suitable type of pickup electrode is a helical spring toroid that can be formed from a 13 millimeter (1/2 inch) O.D. spring wound from No. 18 AWG stainless steel wire, as shown in figure B.4. These electrodes can be made in a variety of toroid diameters slightly smaller than the diameters of the poles being tested. Such springs are flexible enough to expand and roll over most end fittings, and the 13 millimeter (1/2 inch) diameter of the spring gives a rounded contour to reduce corona streamers. One of Western's test crews has found that flat metallic braid, securely taped to the pole, makes a good electrode for DC testing. Shielded cable should be used to connect the pickup electrode to the leakage current meter. Helical spring electrodes may also be used at the high-voltage terminal for test voltages up to 75 kV, although the dielectric current values will be appreciably higher.

(3) Electrode Spacing. The spacing of test electrodes is determined by the test voltage chosen. For example, a 75-kV test voltage would require a 300 millimeter (1 foot) spacing, 150 kV a 600 millimeter (2 foot) spacing, etc. Spacing of electrodes should be measured between the planes of the circles of contact of the electrodes with the tool. The tool should be divided into test segments. One test segment must include the area adjacent to the metal end fitting(s), with one electrode making contact with the metal fitting. In some cases, the test segments may overlap. Tools tested by this method may be tested over the entire length of the tool or for at least the minimum phase-to-ground approach distance, on the hot end, specified in appendix D for the highest voltage worked by the respective Area/District.

(4) Wet Testing. Wet-testing of live-line tools is a requirement of OSHA unless there are other tests that an employer can demonstrate are equivalent. Western allows dry testing only if performing the AC Dielectric Loss (Watts Loss) test method outlined in B.4.2. Western recommends wet testing when performing the high potential dielectric leakage test. Experience has shown that live-line tools with contaminated surfaces which have failed electrically under humid or wet conditions will pass a 100 kV per 300 millimeter (1 foot) test after the tools have been dried. Thus, it is the surface condition of the tool and not its cleanliness that determines the performance when wet. A glossy pole will allow water to bead on the surface, whereas a dull surface will allow the water to spread in a sheeting action. Fairly dirty tools that retain surface gloss will show an increase in leakage current but will likely sustain a 75 kV per 300 millimeter (1 foot) test with an acceptable leakage current level. Conversely, a fairly clean tool with a dull surface which has been wetted may fail at a low-voltage gradient.

(5) Test Instructions.

(a) Support or suspend the tool in a horizontal position, using insulating material, approximately 1.2 meters (4 feet) above the floor. The arrangement shown in figures B.2 and B.3 is acceptable for this test.

(b) Orient the tool to the AC transformer or DC test set such that a minimum leakage current is indicated at a given fixed voltage. Maintain this reference location for all subsequent tests.

(c) Install the corona ring and/or the spring electrode(s) on the tool at the predetermined spacing(s). Spring contact should be maintained around the entire circumference of the tool.

(d) Attach the high-voltage and test leads to the springs so that any sharp edges extend inside the coiled area. Metal conductor spark plug wire may be used for the high-voltage lead which must be routed directly to the nearest electrode. Coil any excess lead in the center of the lead, maintaining a minimum 600 millimeters (2 foot) ground clearance. Use shielded cable to connect the pickup (ground) electrode to a micrometer or other suitable test instrument. Attach the inner conductor of the shielded cable to the pickup electrode and to the ground return meter of the test set. Float the shield at the electrode end and attach the shield to the ground lug on the test set.

(e) Use a clean spray applicator, adjusted to a fine mist, to spray “drugstore grade” distilled water uniformly on the test segment of the pole until droplets just begin to drip from the bottom surface. Apply voltage to the test segment immediately after wetting.

(f) Increase the voltage at a uniform rate of about 3 kV per second to a value equivalent to 75 kV per 300 millimeter (1 foot) of test specimen.

(g) Maintain this voltage for a minimum of 1 minute, and then read and record the maximum leakage current in the ground return meter.

(6) Dielectric Current Evaluation. Sample dielectric current tests should be made on each new tool or when the specimen has clean, uncontaminated surfaces, to establish historical “bench-mark” data. This data can be used for making future comparisons between the inservice tool being tested and the acceptance levels established for that particular diameter of pole and specific electrode configuration.

(a) Typical dielectric (leakage) current values on new FRP poles when tested by the manufacturer, using guarded electrodes and a voltage gradient of 100 kV per 300 millimeters (1 foot), may be in the range of 5 to 25 microamperes depending on the pole diameter, electrode shape and spacing, pole orientation, lead wires, instruments, etc. This range of values can vary from laboratory to laboratory, or from test to test in a given laboratory. Therefore, historical data must be established by performing succeeding tests in exactly the same manner. If nonguarded electrodes are used, the dielectric current values will be appreciably higher.

(b) If the dielectric current decreases while the test voltage is maintained across the specimen, it may indicate that absorbed moisture is drying out during the test. An increasing current may indicate incipient degradation of the specimen.

(c) Significant changes in dielectric current values during a test indicate any or all of the following: contamination, moisture, specimen degradation, or instability of the test setup. If the test setup is not at fault, the tool should be cleaned, dried, refinished as recommended by the manufacturer, and retested.

(d) If, after cleaning, drying, and refinishing, a tool continues to flash over during testing or the dielectric current is significantly above the range established for that particular type of tool, the tool should be removed from service and destroyed or returned to the manufacturer.

LIVE-LINE TOOL TEST REPORT - HIPOT METHOD

ID NO.	TRADE NAME	LENGTH	DIAMETER	Distance From Working End (feet)												
				1	2	3	4	5	6	7	8	9	10	11	12	13

Figure B.1 - Live-Line Tool Test Report - Hipot Method

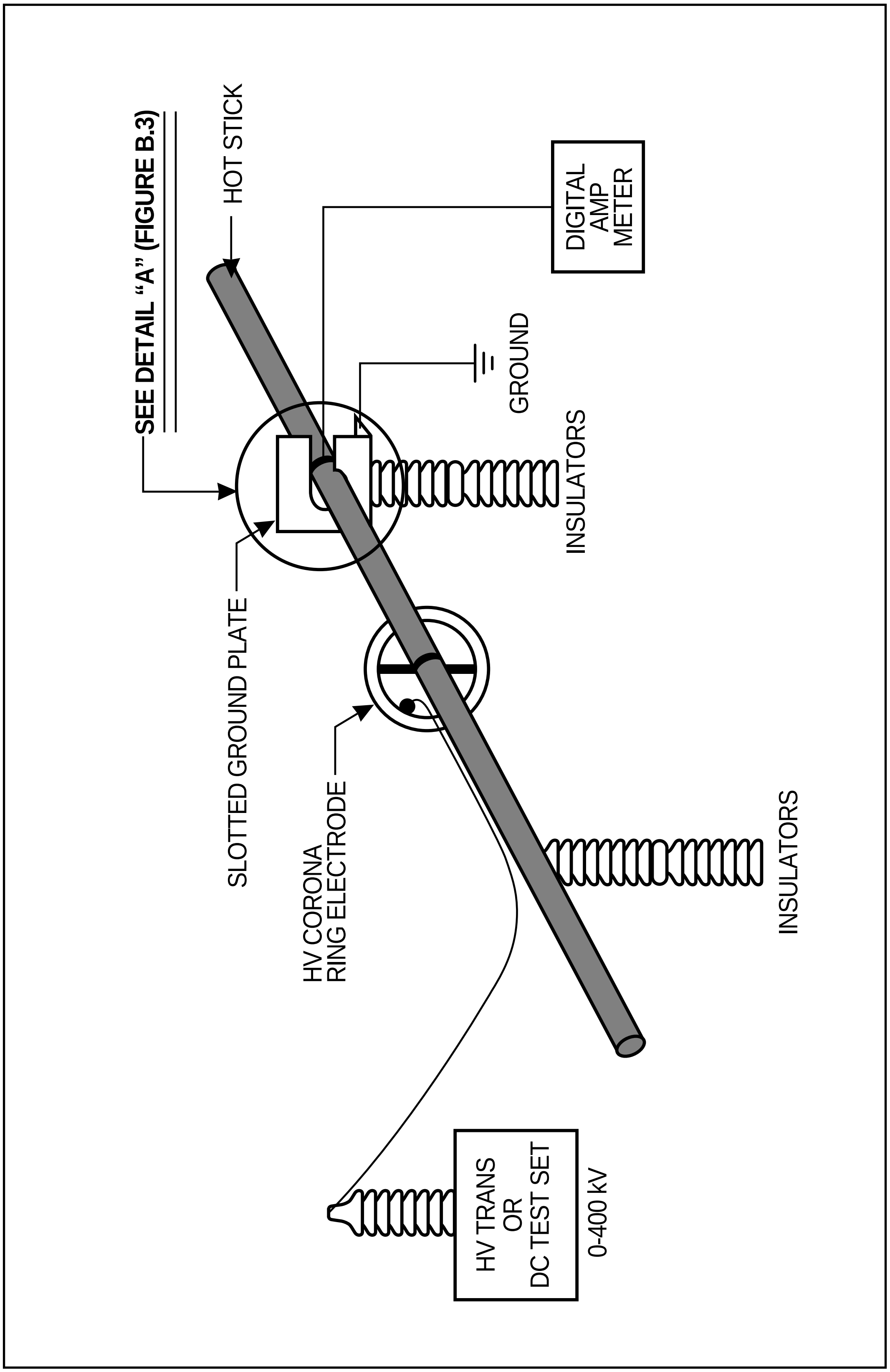

Figure B.2 - Hotstick High-Potential Dielectric Leakage Test Arrangement

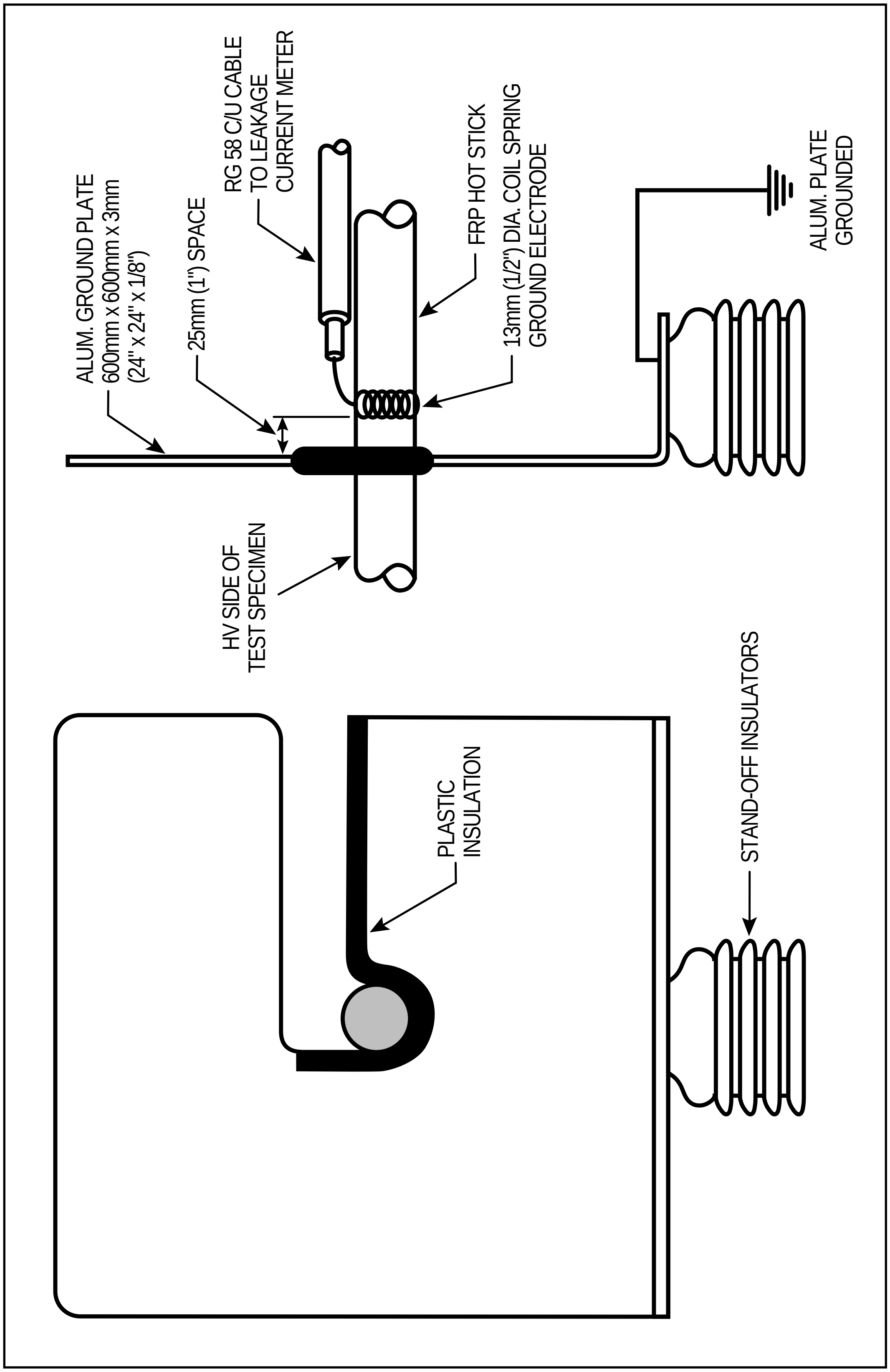

Figure B.3 - Detail “A” of Figure B.2

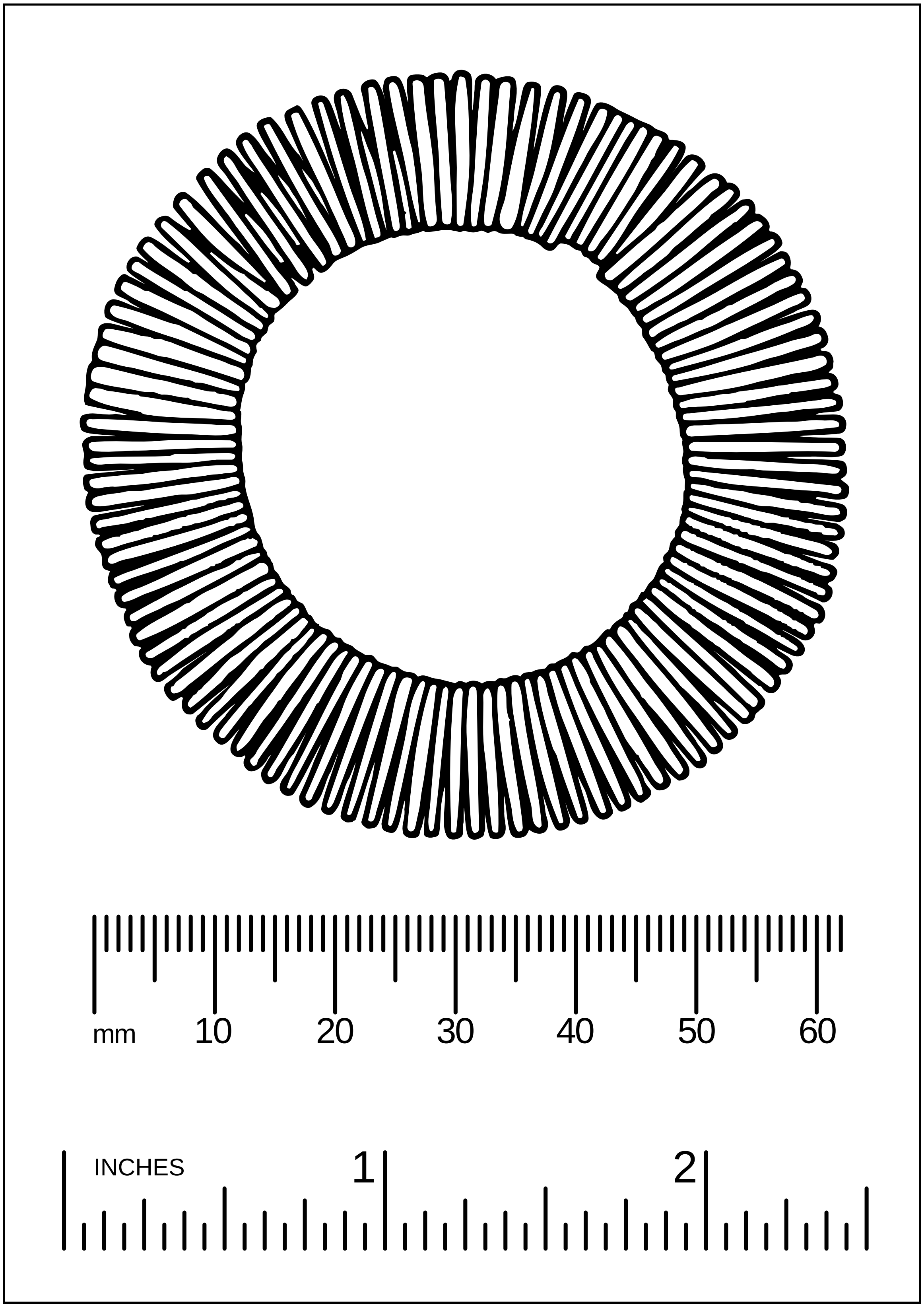

Figure B.4 - Helical Spring Electrode

B.4.2 AC Dielectric Loss (Watts-Loss) Test Method. A sample form for live-line tool test records is shown in figure B.5.

(1) General. The dielectric-loss (watts-loss) method is employed to determine the electrical condition of FRP materials using the “loss” or absorption of energy by the material compared to a reference based on a new or “good condition” value.

(2) Test Equipment. A suitable test voltage, preferably 10 kV or above, but not less than 2,500 V, must be supplied by the test equipment. Provision for the measurement of watts-loss or the loss (leakage) component, Iw, of the total specimen current is required. If desired, the alternating-voltage resistance of the specimen can be calculated as:

$$R = E \div I_W = E^2 \div W$$

(R in ohms, Iw in amperes and W in watts).

Measurement sensitivity should be sufficient to distinguish between 1010 and 1011 ohms resistance.

Note: Capacitance and power factor measurements are not recommended for routine tests of specimens having a capacitance of only a few picofarads. Accurate measurement of these quantities depends on complete specimen-shielded systems, which are not feasible for routine tests.

A guard shield to avoid measurement losses in the equipment itself must be incorporated in the test equipment, including connections to the specimen. Preferably, the test equipment should be able to make measurements using the Ungrounded Specimen Test (UST) method (now recommended by the Doble Engineering Company) with the guard shield at ground potential. However, the Grounded Specimen Test (GST) method may be used, particularly if historical records contain GST data. The watts-loss test is relatively unaffected by extraneous objects in the vicinity of the specimen.

(3) Orientation. The orientation of the watt-loss equipment should be in accordance with the instructions of the test-equipment manufacturer.

(4) Test Procedure. Test electrodes are applied in the selected area. Each electrode may be a conducting strap or collar wrapped tightly around the specimen or clamped to it. A metal fitting attached to the specimen is sometimes used as an electrode. A common arrangement is three electrodes with a spacing of 76 millimeters (3 inches) (see figure B.6). The test voltage is applied to the center electrode and the measurement made between it and the outer electrodes.

For long poles and other specimens of considerable length, measurements may be made at two or more locations along the length using the three-electrode method described in figure B.6. An important test location is at both ends of the insulating tool; i.e., the end normally applied to the energized line and the end held by the worker. An alternative method but less desirable is to use two electrodes separated by a considerable distance, although this usually requires a high-test voltage in order to meet the test-equipment sensitivity requirements specified in subsection C.2. When making a two-electrode measurement, use of the UST method is recommended. Testing by this method requires that, as a minimum, the tool be tested at each end and near the center.

(5) Watts-Loss Method Criteria. The criteria for acceptance of tools checked by the watts-loss method should be based on watts-loss values formulated from historical data. Test criteria for specimens made of the same material and similar dimensions are usually determined from statistical analysis. FRP and many composite insulating materials, when clean and dry, have very low losses on the order of 0.01 watt at 10 kV with the usual three electrode test arrangement (AC resistance greater than 1010 ohms). When the loss exceeds 0.1 watt at 10 kV (resistance of 109 ohms), this usually indicates excessive moisture absorption, dirt, or damage. Equivalent criteria in terms of leakage current can be derived, if desired.

LIVE-LINE TOOL TEST REPORT
AC DIELECTRIC LOSS (WATTS-LOSS) METHOD

Area/District:	Date:
Location of Test:	Equipment Tested:
Last Test Date:	Last Test Sheet No.:

I.D. Number	Test kV	Equivalent 10 kV Readings						Comments	Test Results
		Microamperes			Watts				
		Meter Reading	Multi-plier	Micro-Amperes	Meter Reading	Multi-plier	Watts		

Test Results Key: G - Good B - Bad test, refinish D - Destroy

Figure B.5 - Live-Line Tool Test Report - AC Dielectric Loss Method

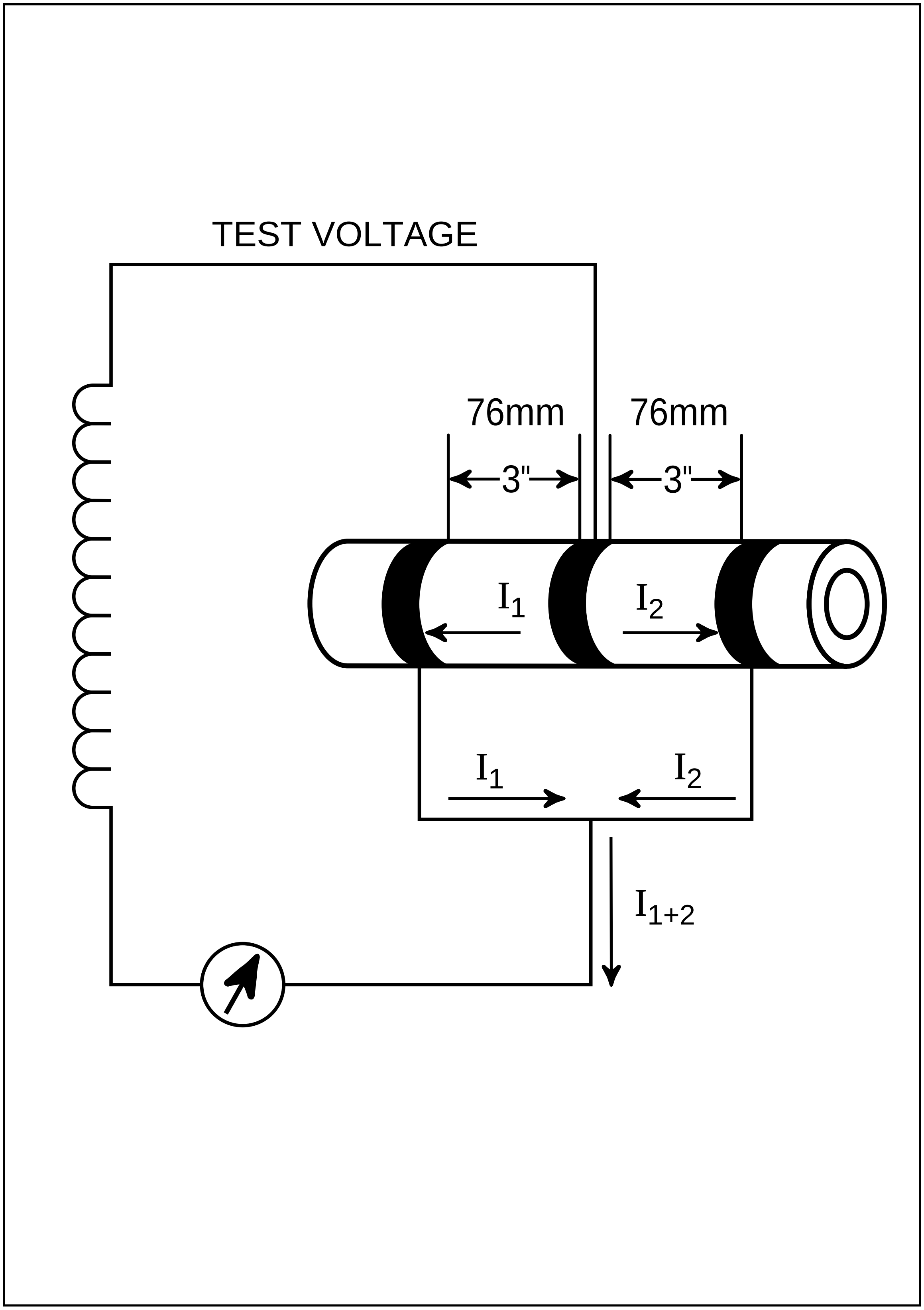

Figure B.6 - Circuit for Hotstick AC Watts-Loss Testing

APPENDIX C - Acceptance Testing and Inservice Inspection and Testing of Insulated Aerial Devices

C.1 General. Periodic electrical and mechanical testing programs are essential in order to evaluate the integrity and stability of the insulating and support components of aerial devices. Therefore, Western's new insulated aerial device test programs shall be as follows:

C.1.1 Acceptance Tests.

(1) Manufacturer's Certification Test.
(2) Inspection and Nondestructive Test.

C.1.2 Periodic Inservice Inspection and Testing Programs.

(1) Inspection and Nondestructive Testing Program.
(2) Electrical Testing Program.

C.2 Acceptance Tests. Electrical acceptance testing for insulated aerial devices is well-defined in ANSI A92.2. All new units are subjected to these acceptance tests and certified before they are placed in service. Western's procurement specifications for new insulated aerial devices shall specifically require the Manufacturer's Certification Test described herein. Additionally, Western's procurement specifications shall also specifically require inspection and nondestructive testing by an independent testing organization as set forth herein.

C.2.1 Electrical Acceptance Test. Following is a brief outline of the electrical acceptance test procedure to be performed by the unit manufacturer:

(1) The assembled insulated aerial devices in operable condition shall be tested on a grounded vehicle or a grounded test stand. The voltage shall be applied to the upper electrode of the insulated boom, and the lower end of the insulated boom shall be connected to ground potential. The test voltage shall be applied at a low voltage and steadily raised until the prescribed test voltage is reached. This voltage shall be maintained for the prescribed test period.

(2) Tests shall consist of rated, double-rated, and at the manufacturer's option, either momentary withstand or switching surge voltage (see the footnote to table C.1). The voltage is raised to rated voltage and the dielectric arm-current recorded. The voltage is then raised to double-rated voltage and held for 3 minutes, recording the dielectric arm-current at the start and end of the 3-minute test period, during which the dielectric arm-current shall neither increase more than 10 percent nor exceed the values given in table C.1.

(3) For units rated 230 kV and above, the corona ring shall not exhibit positive corona streamers during the 60-Hz tests. In addition, any corona discharges during high-voltage tests must not impinge on the insulated portion of the boom.

Manufacturer's Certification Test*						
Rated Line Voltage rms kV	60 Hz Rated Voltage Test		60 Hz Double-Rated Voltage Test		60 Hz Momentary Withstand Voltage rms kV	Switching Surge Withstand Voltage crest kV
	Test Voltage rms kV	Boom Current rms μA	Test Voltage rms kV	Boom Current rms μA		
69	40	40	80	80	120	170
115-138	80	80	160	160	240	340
230	133	133	265	265	400	565
345	200	200	400	400	600	850
500	288	288	575	575	720	1020
765	442	442	885	885	1105	1560

Table C.1 - Manufacturer's Certification Test

*Permanent electrodes are required for all voltages. Test voltages specified for the momentary or switching surge test are based on a 3.0 per unit switching surge factor up to and including 345 kV. A switching surge factor of 2.5 per unit is required for 500 kV and 2.2 per unit for 765 kV. Repeat the switching surge test 10 times with both positive and negative polarity switching surge test waves, with the test waves having a front between 150 and 350 μs.

C.2.2 Inspection and Nondestructive Tests. Following is a brief outline of the inspection and nondestructive testing procedure to be performed after the insulated aerial device is completely assembled, mounted, all other tests completed, and immediately prior to delivery of the equipment:

(1) The inspections and tests shall be performed by a recognized and reputable nondestructive testing organization.

(2) Acoustic emission tests shall be performed on the insulated aerial devices, with transducers placed from the end of the boom in at least eight locations down to the bottom of the main frame assembly.

(3) High-stress areas of the fiberglass boom sections shall be radiographically (X-ray) tested to detect internal cracks or deficiencies not revealed through visual inspections.

(4) Welded areas in steel booms subject to high stress and critical steel castings in booms, turrets, and outriggers shall be X-ray tested to detect cracks, slag, and inadequate penetration of welds.

(5) Critical boom pins and bolts shall be tested by X-ray and/or ultrasonic methods to detect any deficiencies.

(6) Deficiencies detected in critical components by inspection and nondestructive testing shall be corrected by the manufacturer or authorized representative and the previously deficient component(s) retested by the nondestructive inspection and testing methods.

C.2.3 Reports. The contractor shall provide Western with the formal inspection and test results for all acceptance testing.

C.2.4 Witness of Tests. The contractor shall advise Western at least 3 days prior to all acceptance testing so that he or his representative may witness any or all of the tests.

C.3 Periodic Inservice Inspection and Testing Programs. Each operating office shall establish programs for annual inservice inspection and testing on a regular basis. These programs shall include, but not be limited to, the following inspections and tests of all insulated aerial devices.

C.3.1 Inspection and Nondestructive Testing. At approximate 12-month intervals the following inspection and nondestructive tests for insulated aerial devices shall be developed and conducted in cooperation with the equipment manufacturer and/or a recognized and reputable nondestructive testing organization:

(1) A complete visual inspection of each aerial device unit shall be conducted in accordance with a written format, complying with ANSI B30.5, B30.15, and A92.2 as applicable, on the entire unit and subframe area under the unit. Fiberglass and steel boom members, and all pin and wear points, shall be carefully inspected for deformation, cracks, or excessive wear. Hydraulic lines and fittings shall be inspected for cracks and leaks.

(2) Ultrasonic inspections shall be made on all accessible structural pins, including the outrigger pins.

(3) Magnetic particle and/or fluorescent dye penetrant inspections shall be made on critical welds and casting, and on other suspect areas.

(4) Acoustic emission tests in accordance with ASTM specifications and/or as outlined by the Division of Power System Maintenance (A2300) shall be performed on each unit. Acoustic emission testing will only detect a defect that is growing. It will not detect a problem caused at a load lower than the test load.

(5) A dielectric test shall be performed and documented on the oil in each hydraulic system in compliance with ASTM D1816 (VDE) test method with a minimum acceptable dielectric breakdown voltage of 15 kV. A sample test data form is shown in figure C.1.

Deficiencies detected in critical components by any of the above inspections and tests shall be corrected and the equipment appropriately retested before it is returned to service. All other deficiencies shall be scheduled for correction as soon as practicable.

<table>
<tr><td colspan="3">Area/District:</td><td colspan="2">Vehicle Number:</td></tr>
<tr><td colspan="3">Boom Manufacturer:</td><td colspan="2">Vehicle Manufacturer:</td></tr>
<tr><td colspan="2">Breakdown Test</td><td colspan="2">Date:</td><td>Temperature:
(at time of test)</td></tr>
<tr><td>Test Number</td><td>Breakdown Voltage</td><td colspan="3">Comments</td></tr>
<tr><td>1</td><td></td><td colspan="3"></td></tr>
<tr><td>2</td><td></td><td colspan="3"></td></tr>
<tr><td>3</td><td></td><td colspan="3"></td></tr>
<tr><td>4</td><td></td><td colspan="3"></td></tr>
<tr><td>5</td><td></td><td colspan="3"></td></tr>
<tr><td colspan="2">Average Breakdown
Voltage:</td><td colspan="3"></td></tr>
</table>

Figure C.1 - Hydraulic Oil Dielectric Test Report

C.3.2 Electrical Testing Program. A daily preoperative test serves as a go-no-go indication of the actual condition and safety of the FRP boom at that time, on that line, and under those specific weather conditions. While the preoperative test is necessary, it does not electrically evaluate the boom for abnormal conditions, such as possible switching surges. Therefore, at approximate 12-month intervals, each insulated aerial device used in the barehand technique shall be electrically evaluated by means of DC high-potential tests. Electrical test results shall be recorded. A sample test form is shown in figure C.2. These tests may be performed in-house, or by a recognized and reputable nondestructive testing organization, in accordance with the following guidelines:

(1) Electrical Test Electrodes. Western's insulated aerial devices were delivered with (or pre-1969 units retrofitted to include) test electrodes permanently installed on the inside and outside surfaces of the insulated portion of the upper boom for the purpose of monitoring dielectric leakage current, as required by paragraph 3.3.5 of ANSI A92.2. Prior to conducting the following tests, it will be necessary to ascertain that all hydraulic or pneumatic lines and leveling mechanisms, which bridge the insulated section of the boom, are still connected to the test electrodes.

Dielectric Boom Test

3 minute hold

Area/District Office: ______________________ Humidity: ________________percent

Vehicle Number: ______________________ Date of Test: ______________________

Vehicle Manufacturer: ______________________ Rated A.C. RMS

Boom Manufacturer: ______________________ Line Voltage: ______________________

Test No.	Description of Test	Test Voltage (kV)	Leakage Current (µA)		Evaluation	
			Max. Allowable	Measured	Accept	Reject
1	Dry - Upper Boom Insulator only		1000			
2	Wet - Upper Boom Insulator only		100 times dry leakage current or 1000 µA			
3	OPTIONAL Lower Boom Insulator only (flash over test)					
4						

Figure C.2 - Dielectric Boom Test

(2) High-Voltage DC Power Supply. A DC test set with a capability of 400 kV and 2.5 milliamperes is recommended for testing FRP booms certified by the manufacturer for use on phase-to-phase voltages up to 345 kV. However, a DC test set with a capability of 100 kV and 5 milliamperes may be used if both dry and wet tests are performed.

(3) Dielectric Current Metering. Current metering for high-voltage DC test equipment falls into three classifications which are best described by the simplified circuit described by the simplified circuit diagrams shown in Figures C.3a, C.3b, and C.3c.

(4) Boom Orientation. Raise the lower boom so as to clear the nesting cradle by a least 600 millimeters (2 feet) for each 100 kV of test voltage. Bring the upper boom to a horizontal position and hold for 15 minutes to allow any contaminants to settle horizontally in the hydraulic tubing before testing. Prior to and during electrical testing, the truck chassis must be connected to a good ground (station ground mat, structure ground, water piping, or a temporary driven ground rod) by means of a minimum 1/0 copper or equivalent grounding jumper. The case of the DC test set should also be connected to the chassis ground (see figure C.4).

(5) Dry Test Procedure. Test the major upper boom insulation system which includes the FRP boom, hydraulic lines, air lines, and leveling mechanisms. The high-voltage terminal of the test set is connected to the upper (platform end) test electrode. The lower test electrode is connected to the chassis ground (high-side or common ground-return metering) or to the isolated ground return meter terminal with the nonmeasured common ground connected to the chassis ground, as shown in figure C.4. Raise the voltage smoothly to the appropriate test level shown in table C.2 and hold for 3 minutes. Observe and record the dielectric leakage current. Some of the incipient breakdowns that can be detected with this test include deterioration of the insulation resulting from ionization along the surface or internal voids, moisture absorption, component contamination (including contamination of the hydraulic oil), and structural aging. Any significant change in dielectric current values from previous test values warrants an investigation into the cause. If the observed dielectric current exceeds 0.5 microamperes per kilovolt of applied test voltage, the boom should be cleaned, rewaxed or resiliconed, and retested.

(6) Wet Test Procedure. New insulated booms, as delivered, have a waxed or siliconed surface to repel water. This surface must be carefully maintained and replaced as necessary. A dry boom with a chalky or nonwater repelling surface may pass the dry dielectric test and still be a virtual short circuit on a humid morning or after a brief shower. Therefore, a wet test is recommended for all test voltages, and is required for all booms rated for 115 kV and above if the test set capability is limited to 100 kV. To conduct the wet test, wet the insulated FRP portion of the boom thoroughly, using distilled water applied with a clean spray applicator. Retest the upper insulation system as in (5) above within 3 minutes of wetting. The observed dielectric leakage current should not exceed 100 times the dry leakage current, and should never exceed 1 milliampere, at rated test voltage.

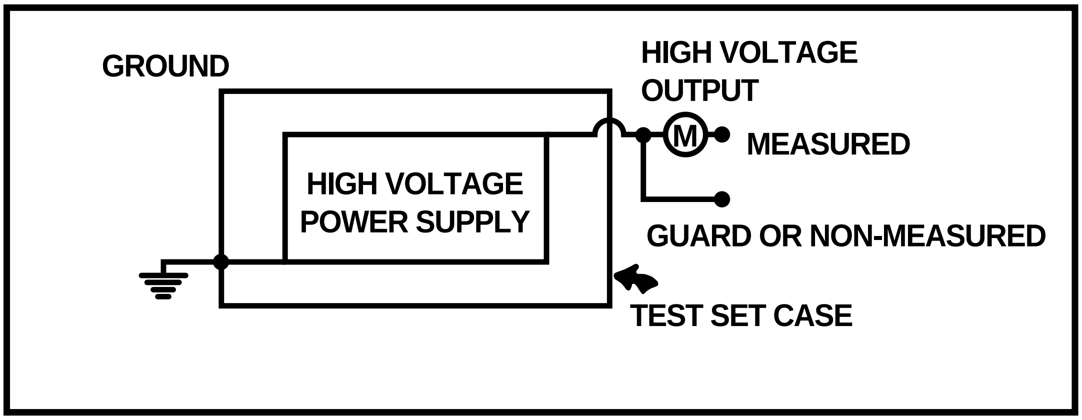

Figure C.3a
Metering in the high voltage output lead is the most simple, safe, and reliable method.

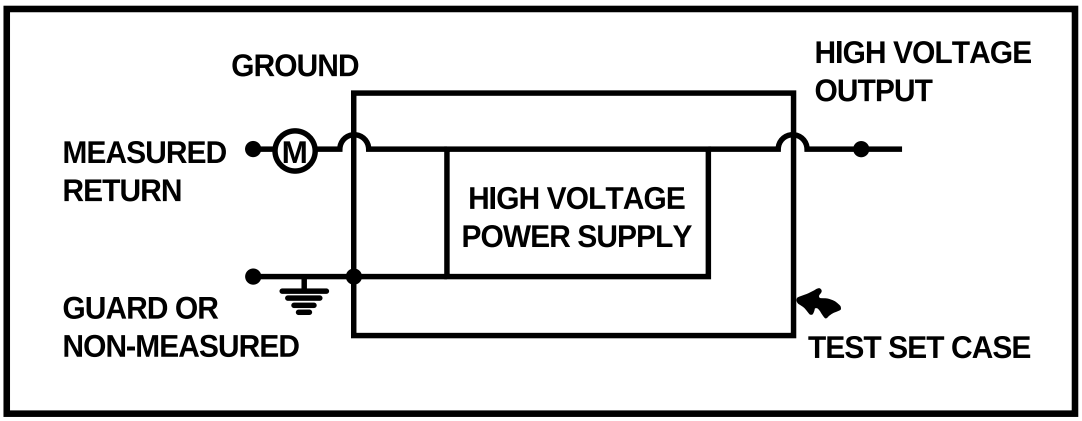

Figure C.3b
Metering in the isolated ground return is useful but may pose a safety hazard if the connection is on the control box instead of the high voltage cabinet. A coaxial lead with the shield grounded should be used.

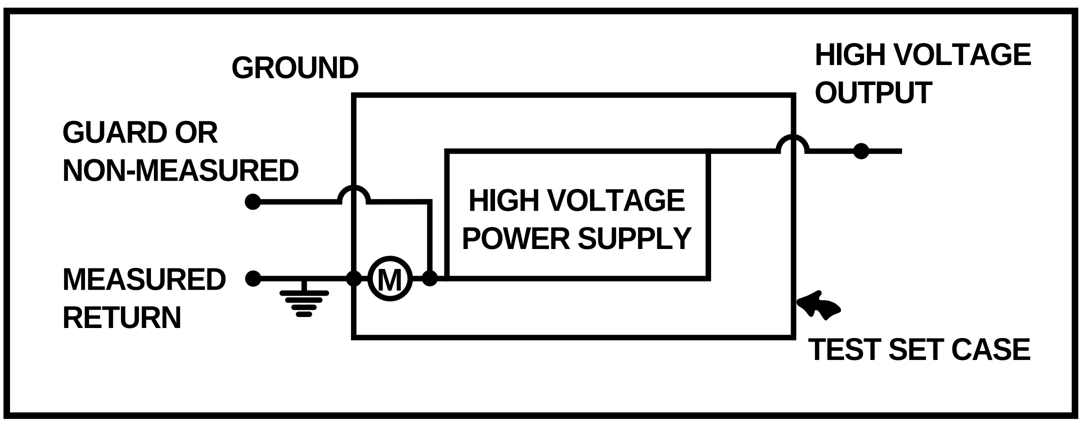

Figure C.3c
Metering in the common ground return is a convenient inexpensive method but subject to error due to equipment condition.

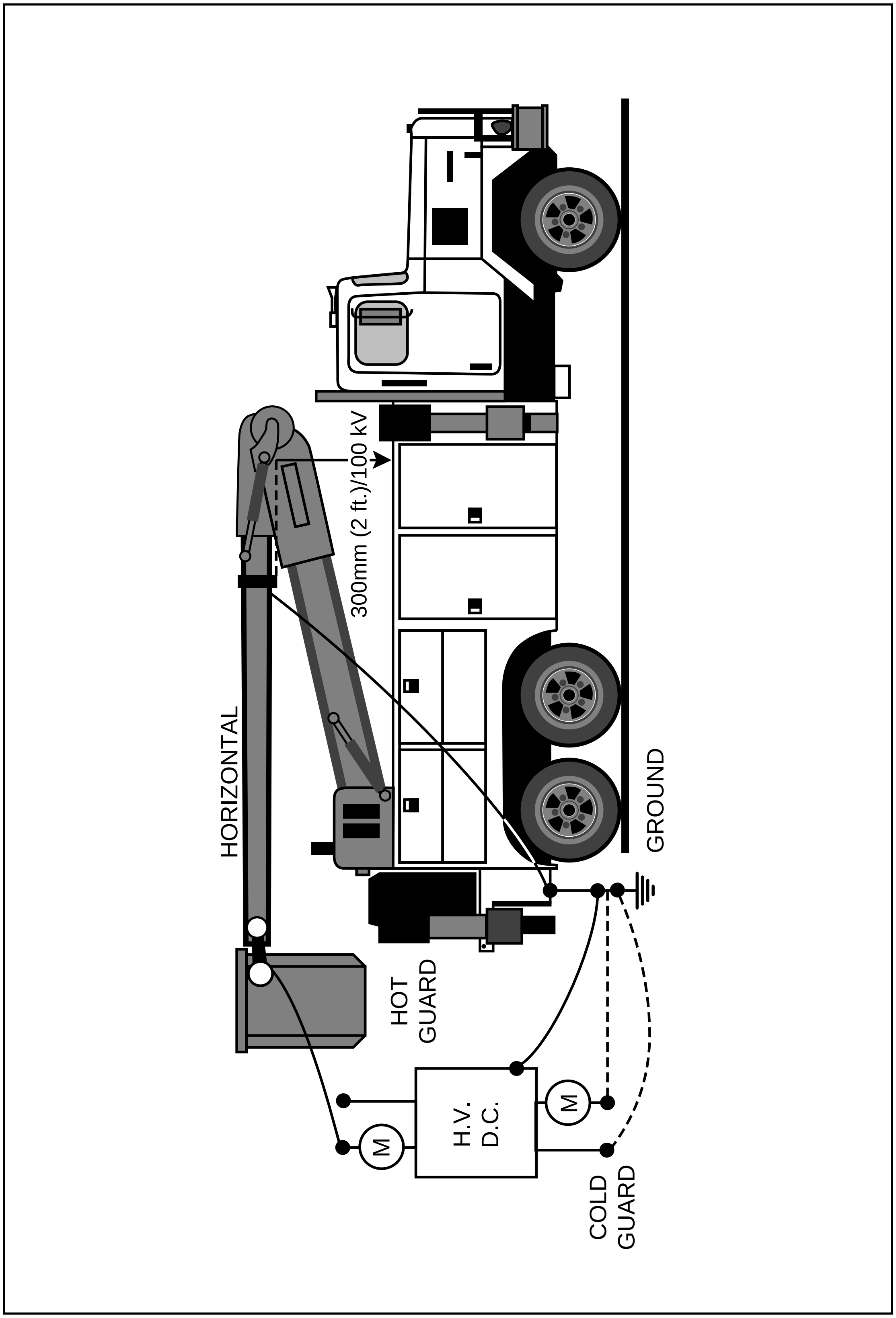

Figure C.4 - Typical Test Setup for High-Voltage DC Testing

DC MAINTENANCE 3-MINUTE TEST

Rated Line Voltage	DC Test Voltage	Maximum Allowable Dielectric Current
rms kV	kV	microamperes
69	100	100*
115-138	160	160*
230	265	265*
345	400	400*
500	575	575*

* Maximum Leakage Current - normal leakage current will be much lower.

Table C.2 - DC Maintenance 3-Minute Test

C.3.3 Records. Records of all inspections, tests, and corrective maintenance on insulated aerial devices shall be maintained in the responsible operating office.

APPENDIX D
Minimum Electrical Approach Distances For Electrical Workers

D.1 Minimum Approach Distances. AC minimum approach distances to live parts for unknown transient over voltage (TOV) control without HLO up to an altitude of 3,300 feet shall be in accordance with table D.1. Specific applications shall be in accordance with Appendix A (and related sections) of the PSSM.

Voltage in Kilovolts Phase-to-Phase	Distance to Employee			
	Phase-to-Ground		Phase-to-Phase	
	(ft-in)	(m)	(ft-in)	(m)
0 to 0.050*	Not Specified Avoid Contact		Not Specified Avoid Contact	
0.051 to 0.300*				
0.301 to 0.750*	1-0	0.31	1-0	0.31
0.751 to 15.0	2-2	0.65	2-3	0.67
15.1 to 36.0	2-7	0.77	2-10	0.86
36.1 to 46.0	2-9	0.84	3-2	0.96
46.1 to 72.5	3-3	1.00	3-11	1.20
72.6 to 121	3-2	0.95	4-3	1.29
138 to 145	3-7	1.09	4-11	1.50
161 to 169	4-0	1.22	5-8	1.71
230 to 242	5-3	1.59	7-6	2.27
345 to 362	8-6	2.59	12-6	3.80
500 to 550	11-3	3.42	18-1	5.50
765 to 800	14-11	4.53	26-0	7.91

*For single-phase systems, use the voltage to ground.

Note: Minimum approach distances for electrical workers without an active HLO shall be restricted to this table.

For voltages outside this table, see the NESC, 1993 edition or OSHA 1910.269. (Interpolation is not allowed.)

Table D.1 - AC Live-Line Minimum Electrical Approach Distance for Electrical Workers (Unknown TOV Control)

D.2 Metal Deductions. Some live-line tools or equipment have metal parts. When using these tools, the minimum electrical approach distance must be increased to protect the worker. A simple method may be used to determine the amount to increase the minimum electrical approach distance by:

Length of metal x 1.15 = Metal distance
Metal distance + Minimum Electrical Approach Distance (table D.1) =Total*
*This total is the new minimum safe electrical approach distance.

In the case of several metal parts, the length of the individual parts may be added together to calculate one overall length. This number can then be substituted into the formula for “length of metal.”

D.3 Transient Overvoltage Control Above 72.5 kV. Table D.2 reflects AC minimum electrical approach distances to live parts for maximum known transient overvoltage (TOV) control on Western transmission lines with an active HLO for altitudes up to 3,300 feet.

Voltage in Kilovolts Phase-to-Phase	Distance to Employee			
	Phase-to-Ground		Phase-to-Phase	
	(ft-in)	(m)	(ft-in)	(m)
0.301 to 0.750	1-0	0.30	1-0	0.30
0.751 to 15.0	2-2	0.66	2-3	0.69
15.1 to 36.0	2-7	0.79	2-10	0.86
36.1 to 46.0	2-9	0.84	3-2	0.97
46.1 to 72.5	3-3	0.99	3-11	1.19
72.6 to 121	2-9	0.84	3-11	1.19
138 to 145	3-2	0.97	4-6	1.37
161 to 169	3-6	1.07	5-2	1.57
230 to 242	4-6	1.37	6-9	2.06
345 to 362	6-8	2.03	10-4	3.15
500 to 550	11-3	3.42	18-1	5.50
*(W/PPG)	7-6	2.29	11-6	3.51

* These values are specific to the Olinda-Tracy 550kV transmission line in the Sacramento Area Office, with portable protective gaps in place.

Table D.2 - AC Live-Line Minimum Electrical Approach Distance for Electrical Workers (Known TOV Control for Western Transmission Lines)

NOTE: For voltages above 72.5 kV, the minimum electrical approach distance may be reduced (from the required distances listed in table D.1 and D.2) for a specific line in accordance with NESC, 1993 Edition and OSHA 1910.269, if the maximum anticipated transient overvoltage is known for the worksite. An engineering analysis to determine transient overvoltages for a specific line for reduced clearances shall be determined in accordance with OSHA 1910.269, Appendix B. Coordination with A2300 is recommended to determine maximum anticipated transient overvoltages.

D.4 Altitude Correction Factors. To calculate the minimum approach distances using altitude correction factors, the following example may be used. This example is presented to stress that the multiplier applies only to the electrical portion of the minimum electrical approach distance, not to the inadvertent movement distance added in the 1993 Edition of the National Electrical Safety Code (NESC) and OSHA 1910.269. The user must decide whether to interpolate between altitudes or use the next higher altitude. The following example is chosen for an altitude listed in table D.2 to avoid confusion. Minimum approach distance tables with altitude correction factors applied are available in Appendix A of the PSSM.

Assume you have a 345-362 kV transmission line at 2,400 meters (8,000 feet) at the worksite.

From table D.1, the minimum phase to ground approach distance for
345-362 kV (at 900 meters (3,000 feet) and below) is 2.59 meters (8 feet, 6 inches).
2.59 meters = 8.5 feet.

Subtract the NESC inadvertent movement distance of .31 meters (1 foot) and the value becomes, 2.59 meters - .31 meters (8.5 feet - 1 foot) = 2.28 meters (7.5 feet) (referred to as the adjusted approach distance).

From table D.3, the altitude correction factor for (8,000 feet) is 1.14. Multiply the adjusted approach distance by the altitude correction factor, 2.28 meters x 1.14 (7.5 feet x 1.14) = 2.60 meters (8.55 feet).

Add back the NESC inadvertent movement distance of .31 meters (1 foot), the minimum phase to ground approach distance becomes, 2.60 meters + .31 meters (8.55 feet + 1 foot) = 2.91 meters (9.55 feet or 9 feet, 7 inches). Hence, the increase in altitude results in an increase of .32 meters (1 foot, 1 inch).

NOTE: The NESC inadvertent movement distance is .31 meters (1 foot) from 0.301 kV to 0.750 kV, .61 meters (2 feet) from 0.751 kV to 72.5 kV, and .31 meters (1 foot) above 72.6 kV.

Phase-to-phase minimum approach distances corrected for altitude are derived by the same method.

D.5 Portable Protective Gaps. Portable protective gaps are used during live-line maintenance operations to limit to a specified value, for the duration of the work and specifically at the work site, the transient over voltages (TOV's) that are expected at the work site. The gap, consisting of two metal rods mounted on a length of a fiberglass stick, is fixed to provide a specific voltage level that corresponds to a given probability of sparkover of the portable protective gap.

Due to Western's compact 500kV transmission structure design in the Sacramento Area, the live-line minimum approach distance is restricted to between 6' 6" and 7' 6". Western has developed portable protective gaps that provide protection for the worker while performing live-line maintenance on the transmission line. Specific TOV's must be determined for given probable operating conditions of a specific system.

D.6 Substation Approach Distances. The minimum electrical approach distance in a substation may be greater than the manufacturer's air gap operating electrical clearance. Therefore, the minimum safe work distance for the voltage to be worked must be maintained for the worker's safety regardless of the manufacturer's air gap.

Example: A 69-kV disconnect switch having a manufacturer's air gap of 635 millimeters (25 inches) does not meet the minimum approach distance of 990 millimeters (39 inches).

NOTE: At 72.6 kV, the inadvertent movement is reduced to 300 millimeters (12 inches).

The inadvertent movement factor may be reduced within the switch air gap by inserting an approved electrically-rated insulating barrier. The use of a barrier should be coordinated with A2300 and a PSSM variance must be prepared.

ALTITUDE CORRECTION FACTOR		
Altitude		Correction Factor
(ft)	(m)	
3,000	900	1.00
4,000	1,200	1.02
5,000	1,500	1.05
6,000	1,800	1.08
7,000	2,100	1.11
8,000	2,400	1.14
9,000	2,700	1.17
10,000	3,000	1.20
12,000	3,600	1.25
14,000	4,200	1.30
16,000	4,800	1.35
18,000	5,400	1.39
20,000	6,000	1.44

Table D.3 - Altitude Correction Factors

APPENDIX E - Specific Live-Line Problems and Solutions